BMJ Open

An evaluation of the nutrient contents of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-021387
Article Type:	Research
Date Submitted by the Author:	23-Dec-2017
Complete List of Authors:	Moore, Bernadette; University of Leeds , School of Food Science and Nutrition; University of Surrey Horti, Annabelle; University of Leeds , School of Food Science and Nutrition Fielding, Barbara; University of Surrey, Department of Nutritional Sciences
Keywords:	Yogurt, Sugar, Children, Obesity

TITLE PAGE

Title

An evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Author names

J. Bernadette Moore[1,2], Annabelle Horti[1] and Barbara A. Fielding[2]

Author affiliations

[1]School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK

[2]Department of Nutritional Sciences, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, UK

Corresponding author

Dr. J. Bernadette Moore

University of Leeds

School of Food Science and Nutrition

Leeds

LS2 9JT, UK

Tel: +44 (0) 113 343 9900

Email: j.b.moore@leeds.ac.uk

Running title

Nutrient content of yogurts in the UK

Keywords

Yogurt, Sugar, Children, Obesity

Abstract

Objectives: To comprehensively survey the sugar and nutrient contents of yogurt products available in UK supermarkets across categories, in particular those marketed to children.

Design: A cross sectional survey of yogurt products available in the UK's supermarkets in November 2016.

Methods: Data were collected from five major online UK supermarkets and a process flow strategy was used to place yogurts into eight categories: children's, dairy alternatives, dessert, drinks, fruit, flavoured, natural/Greek style and organic. A comprehensive database of product information for 915 unique products was created and analysed.

Results: The sugar, fat, protein, calcium and energy contents were highly variable across categories, and the ranges were extremely broad. Although lower than the dessert category, the median[range] sugar content of children's (10.8g/100g [4.8, 14.5]), fruit (11.9 [4.6, 21.3]), flavoured (12 [0.1, 18.8]), and organic (13.1 [3.8, 16.9]), yogurt products were all well above 10g/100g, and represented >45% of total calories. Only 3 of 101 children's yogurt and fromage frais products surveyed were low in sugar (</= 5g/100g). Natural/Greek yogurts had a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% vs 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) and total sugar contents (5.0 [1.6, 9.5], largely lactose) than all other categories. Low-fat products had less sugar and energy than high-fat yogurts. Within the children's category, fromage frais had higher protein (5.3 [3.3, 8.6] g/100g vs. 3.2 [2.8, 7.1]; P <0.0001) and calcium contents (150 [90, 240] mg/100g vs. 130.5 [114, 258]; P= 0.0015) than yogurts.

Conclusions: While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in nutrient contents. We conclude, not all yogurts are as healthy as perhaps consumers perceive them, the majority are high in sugars and reformulation for the reduction of added sugars is warranted.

Strengths and limitations of this study

- This work comprehensively examines for the first time the energy and nutrient (sugar, fat, protein, calcium) contents of yogurt products available in UK supermarkets.
- The results highlight the very high content of sugar in most yogurt product categories; in particular organic yogurts, products marketed to children, and yogurt products with added plant stanols marketed for cholesterol lowering, had concerningly high levels of added sugars.
- While a strength of our study is that we analysed 915 unique products from five major UK supermarkets with an online presence covering 65% of the UK grocery market share, a limitation is that not all supermarkets were surveyed.

Introduction

The association between dairy foods and disease risk has often been contradictory, likely due to inherent diversity in the nutrient contents and food matrices of different dairy products.[1] Yogurt is the product of milk fermented with the lactic cultures *Streptococcus thermophiles* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, which can be enhanced with other probiotic cultures such as *Lactobacillus acidophilus* and *Bifidobacterium bifidus*.[2] Consumption of fermented dairy products has long been considered to be beneficial to digestive and overall health.[3] The beneficial probiotic and immune regulatory effects of yogurts underpin their recommendation as a healthy food for babies and children.[4] Multiple regulatory bodies, including the European Food Safety Authority, have approved health claims related to yogurt consumption and reduction in symptoms caused by lactose maldigestion.[5] In addition to probiotics, yogurt is a good source of protein, calcium and vitamin D and its consumption has been associated with lower risk of obesity and cardiometabolic risk in both children and adults.[6 7]

Evidence is accumulating that frequent yogurt consumption may be associated with healthier metabolic profiles in both children and adults.[8 9] In adults, increased yogurt consumption has been associated with lower levels of circulating triglycerides, glucose and lower systolic blood pressure;[9] and several recent meta-analyses have demonstrated that increased yogurt consumption is inversely associated with the risk of developing type 2 diabetes.[10-13] Notably, across three large American cohort studies (the Health Professionals Follow-Up Study and the Nurses' Health Studies I and II) in >190,000 adults and >30 years follow-up; while there was no effect of dairy on incident type 2 diabetes (T2D), yogurt intake specifically was inversely associated with T2D risk across the three cohorts with a pooled hazard ratio of 0.83 (0.75, 0.92) for one serving/day.[12] Although confounders were statistically accounted for, an acknowledged limitation to these epidemiology studies is the evidence that yogurt is a general marker of healthy dietary habits.[9 14] Data are more equivocal regarding yogurt consumption and cardiovascular disease risk, although one study suggested a possible lowered risk at higher consumption levels of yogurt (>200g/d),[15] a more recent and comprehensive meta-analysis showed no benefit.[16] High quality and adequately powered randomised controlled trials are lacking however.

Prospective cohort studies have, in general, shown inverse associations between yogurt consumption and changes in waist circumference, weight and risk of overweight or obesity; with some inconsistencies between studies.[17,18] More recently, in an elderly Italian population cohort of >4,000 at high cardiovascular risk, consumption of whole-fat yogurt (but not total yogurt consumption) was associated with changes in waist circumference and higher probability for reversion of abdominal obesity and lower risk of diabetes.[19,20] This is in line with a previous systematic review of observational studies on the relationship between dairy fat, obesity, and cardiometabolic disease; in 11 of 16 studies included in the review, high-fat dairy intake was inversely associated with measures of adiposity.[21] While dietary

guidelines vary by region, most countries make dietary recommendations for the consumption of dairy products because of the strong evidence for role of dairy products in meeting nutrient intake requirements.[22] In both the US and UK, current dietary guidelines recommend low-fat and low sugar dairy products because of obesity related concerns; however, a growing number of recent studies suggest that high-fat dairy consumption is associated with a lower risk of obesity and diabetes[21 23-25] and there is ongoing wider debate regarding dietary guidance related to fat, refined sugars, and cardiovascular disease risk.[26]

In the UK, on average, children consume more yogurt than adults, and children under three years of age have the highest intakes.[27] Yogurt contributes significant amounts of key nutrients to babies and children up to 10 years of age, including: calcium, phosphorus, vitamin D, iodine and riboflavin.[27] Yogurts are often recommended to be part of children's diets due to their high calcium content and its positive effect on bone development.[28] Calcium also has a positive effect on teeth and high intakes of milk and yogurt products in multiple studies have been associated with reduced tooth erosion.[29] However, although there is good evidence to suggest that yogurt can be beneficial to health, products on the market may vary widely in sugar content and yogurt marketed specifically to children may be higher in added sugars.[30 31] Dairy is a significant contributor to the intakes of added sugars by children and adults.[32] Diets high in added sugars are now unequivocally linked to obesity and dental caries, prompting the World Health Organisation and other regulatory bodies in updating dietary guidelines to strongly advocate for restricting added sugar consumption to less that 10% of total energy.[33 34] With an alarming 58% of women and 68% of men along with 1 in 3 of UK children aged 10-11 years overweight or obese in 2015,[35] the UK's guidelines more stringently recommended the restriction of dietary sugars to less than 5% of total daily energy.[36] As part of a plan to combat childhood obesity, the UK government has implemented an industry soft drinks levy that will take effect in April 2018 and commissioned a structured programme of monitored sugar reduction as part of wider reformulation tackling calories, salt and saturated fat.[37] The initial focus was on the top 9 food categories (after soft drinks and fruit juices and smoothies) that contribute the most to children's sugar intakes. These are: chocolate, confectionery, biscuits, breakfast cereals, cakes, morning goods (such as croissants, buns and waffles), ice cream, yogurt and sweet spreads/sauces. Yogurt was one of the products identified and highlighted for a 20% reduction of sugar by 2020, with guidelines given for energy per portion size of 120kcal sales weighted average; 175kcal maximum per portion and an allowance made for lactose (3.8g/100g).[37]

In this context then, the aims of this work were to perform a comprehensive survey of yogurt products within the major UK supermarkets, and to evaluate their nutrient contents across categories, paying particular attention to products marketed to children.

Experimental methods

Data collection

Data were collected from five major UK online supermarkets (Asda, Morrisons, Sainsbury's, Tesco and Waitrose) that account for 75% of the UK market share.[38] Websites were searched from 07/10/16-16/11/16 using 'yogurt' as a search term. After considering the product groupings commonly used by online supermarkets, eight categories (children's, dairy alternatives, dessert, drinks, flavoured, fruit, natural/Greek, organic) and a systematic process flow strategy for product placement (Fig. 1) was decided upon *a priori*. For example, soya based yogurts were placed in the 'dairy alternative' category, whereas Greek style yogurts with added honey were in the 'flavoured' category. In scrutinising the children's category, the ingredients lists were used to evaluate presence or absence of yogurt or fromage frais cultures. The dessert category contained both yogurt-based and other products (eg. jellies and puddings) that contained no cultures but had come under the supermarket category of yogurts. 'Fruit' was defined liberally, for example many products were made with either curd or purees and for lemon products in particular, often with juice. For the classification of high and low-fat, the cut-offs defined by EU regulations were used; where a low-fat product is defined by a maximum of 3g of fat /100g or 1.5g/100ml for drinks; and low sugar is defined by a maximum of 5 g sugar/100g.[2] Data were screened for duplicates and a non-redundant database of product information was created that included: nutrient information, serving size, size of pack, claims on pack and ingredients. Nutrient information was downloaded from the brand's own website where possible. Information on macronutrients, including energy, fat, saturated fat, carbohydrates, sugar, fibre and protein were collected, as well as any information on micronutrients. All data were independently double-checked and 5% of all entries were randomly selected and verified.

Data analysis

Pivot tables in Excel were used for building and manipulating the product database and statistical analyses were done utilising Graph Pad Prism 7.0c. Normality was examined using the D'Agostino-Pearson omnibus normality test and comparisons across all categories were made using the non-parametric Kruskal-Wallis test with Dunns multiple comparisons. For comparisons of two categories, again in not observing normal distributions, the non-parametric, two tailed Mann-Whitney test was applied.

Results

Nine hundred and fifteen products available online during the period of the survey were included in the analysis. Sixty-five products were available in all five supermarkets, although national branded products dominated the products available (n=648 national vs n=267 own brand products; Table 1). There were small but statistically significant differences found in the nutrient profiles of national and own brand products (Table 1). Specifically, own brand products were slightly higher in energy (96 vs 90 kcal/100g; *P*=0.0013), fat (2.9 vs 2.6 g/100g; *P*=0.0019), saturated fat (1.9 vs 1.8 g/100g; *P*=0.0053) and sugar (12.0 vs 11.4 g/100g; *P*=0.0003). While the protein content of own brand products was slightly lower than national brand products (4.0 vs 4.2 g/100g; P=0.0002), there was no difference in the calcium contents. In general, data for calcium, fibre and micronutrients were less available; data were identified for calcium for 57 of 267 (21.3%) own brand and 369 of 648 (56.9%) national brand yogurt products (Table 1).

The sugar content varied enormously both within and across yogurt categories (Fig. 2a). With the exception of the natural/Greek category, the median sugar contents of all categories were well above the 5g/100g maximal threshold considered 'low sugar' for nutrition claims.[2] Products within the dessert category, unsurprisingly, had the highest median and broadest [range] of total sugar at 16.4 [1.5, 32.6] g/100g (Fig. 2a). However, the children's, flavoured, fruit and organic categories all had relatively high, and similar, median sugar contents ranging from 10.8g/100g (children's) to 13.1g/100g (organic). As the natural/Greek category contained no added flavouring, it had the lowest amount of sugar per product (5 [1.6, 9.5]g/100g); this is likely a fair estimate of the median content of lactose content of yogurts and, notably, is somewhat higher than the allowance of 3.8g/100g specified in the guidelines. The dairy alternatives and drinks categories also had sugar medians higher than the 5g/100g threshold, nonetheless these were still significantly lower that the children's, flavoured, fruit and organic categories with median[ranges] of 9.2[0.4,12.5] and 9.1[2.3,16.5] g/100g (Fig. 2a).

Somewhat in contrast to sugar, as seen in Fig. 2b, many yogurt categories (children's, dairy alternative, drinks, fruit, natural/Greek) had median levels of fat lower than the thresholds considered 'low-fat' for nutrition claims (3g/100g for food and 1.5g/100mL for drinks).[2] While flavoured and organic yogurts were just over this threshold with medians of 3.6[0, 9.6] and 3.9 [0, 10.1]g fat/100g yogurt, the dessert category contained the highest median amount of fat and had the broadest range at 5.2[0, 26.7] g/100g (Fig. 2b). The drinks category had the lowest median fat contents at 1.5[0, 3.0]g/100g, but the fruit and natural/Greek categories were also relatively low with medians of 1.7[0, 8.9] and 1.7[0, 10.1]g/100g respectively (Fig. 2b).

The natural/Greek and the children's categories had the highest median protein contents at 5.4[2.2, 11.0] and 5.3[2.8, 8.6]g/100g yogurt. The higher protein median for the children's category was influenced, as expanded on below, to a significant degree by a large percentage of high protein fromage

frais products. The dessert, fruit, flavoured and organic categories had very similar median protein contents 4.0-4.5 g/100g, whereas drinks and dairy alternatives contained the least amount of protein at 2.7 [1.3, 5.9] and 3.6[0.6, 5.2]g/100g. Calcium values were less frequently reported, but median values between yogurt categories were broadly similar ranging from 116-150 mg/100g (Fig. 2d). Mimicking protein, the natural/Greek and the children's categories had the highest calcium contents. The dessert category, again not surprisingly, contained significantly more energy/100g (Fig. 2e) and more energy/serving (Fig. 2f) than any other category. Although the children's category had the least energy/serving (Fig. 2f), this was clearly because of smaller serving sizes. When expressed as kcal/100g, the median energy of children's yogurts was similar to products in the dairy alternative, flavoured, fruit and organic categories (ranging from 79-100g/100g), and these were significantly higher than the median (65g/100g) of the natural/Greek category (Fig. 2e).

In examining the macronutrient content (as %energy) of yogurts across categories, it was clear that the majority of carbohydrates in yogurt products are derived from sugars (Table 2). Carbohydrate content ranged from the extremes of 34.7% (natural/Greek) to 62.4% (drinks) of energy content, but all other categories were tightly bunched at 48.5-56.7% carbohydrate content. The natural/Greek category was significantly higher in protein (32.3%) than any other category, while the dessert category had the least amount of protein (10.8%) and highest percentage of fat (32.6%; Table 2). Although fruit and flavoured yogurts had very similar sugar contents, fruit yogurts contained small, but appreciably more, amounts of fibre compared to flavoured or natural/Greek yogurts (Table 3).

It has previously been reported from an analysis of a US database that low-fat products, including yogurts, contain more sugar than their higher fat counterparts.[39] However, in comparing high (n=383) and low-fat (n=530) yogurt products here, we did not observe this. High-fat yogurt products had significantly higher amounts of sugar in comparison to low-fat yogurts (13.1[1.6, 32.6] versus 10.3[0.4, 21.5]g/100g; Fig 3a), and much higher median and broader range of fat (5.5[1.6, 26.7] versus 1.4[0, 5.7]g/100g; Fig 3b). Low-fat yogurts contained more protein than high-fat products (4.4[0.9, 11.0] versus 3.9[0.4, 9.5]g/100g; Fig 3c), and much lower energy per 100g (79[28.0, 161.0] versus 125[36, 445]g/100g; Fig 3d).

While fromage frais is also a fresh lactic fermented milk product, it is made with cheese cultures rather than yogurt cultures. In most of the categories, less than 5% of products were fromage frais and were not separated out. However, in the children's category, fromage frais dominated, representing 60% of products (n=62 vs n=39 yogurts) so their nutrient contents were assessed separately (Fig. 4). While there was no difference in the sugar content of children's yogurt and fromage frais (Fig. 4a); fromage frais products had lower fat (Fig. 4b; $P<0.0001$), higher protein (Fig. 4c; $P<0.0001$) and higher calcium (Fig. 4d; $P<0.01$) compared to children's yogurts. Although there was no difference in energy/100g (Fig.

4e), the energy/serving was significantly lower for fromage frais (Fig. 4f; $P<0.0001$) reflecting its often smaller serving size.

Discussion

We have comprehensively evaluated yogurt products sold in the major online UK supermarkets in November 2016, examining nutrient contents across categories including those products marketed to children. Our results highlight that that, indeed, the total sugar content of yogurts is high in all categories, with the exception of the natural/Greek category. Very few products qualified for a 'low sugar' claim (less than 5g/100g) and almost none in the children's category. This is concerning given both the continued increase in childhood obesity and prevalence of tooth decay among children starting school (28%).[40] Tooth extractions are shockingly the primary reason children aged 5-9 are admitted to hospital (with general anaesthetic) in the UK.[41] Moreover, in 2015/16 more than 1 in 5 children in Reception (age 4-6), and 1 in 3 children in Year 6 (age 10-12) were measured as obese or overweight in England.[42] While yogurt may be less of a concern than soft drinks and fruit juices, the chief sources of added sugars in both children and adult's diets; what is worrisome is that yogurt, as a perceived 'healthy food', may be an unrecognised source of added sugars in the diet. Indeed, a potentially surprising observation from our data is that, after the dessert category, it was organic yogurts that had the highest median sugar content (13.1g/100g). An added confusion for the consumer is understanding that the total sugars on the label includes the intrinsic sugar lactose plus added sugars. Although current UK labelling laws do not require the declaration of added sugars on nutrition labels, this has been recently mandated in the US; companies have until 2020 or 2021 to implement depending on their size.[43]

The UK guidelines for sugar reduction in the yogurt and fromage frais category, do not apply to dairy desserts, natural/unsweetened yogurt and fromage frais, and yogurt/dairy drinks (although 'any sugar-sweetened yogurt and dairy drinks that are excluded from the soft drinks industry levy will become part of the sugar reduction programme').[37] But it was interesting to note the median of sugar content in plain, natural/Greek yogurts (5.0 g/100g), which we take as a reasonable proxy for lactose, was much higher than the allowance of 3.8g/100g that the UK guidelines agreed on for lactose. It should be noted that the guidelines have been made, in consultation with industry, on sales weighted averages so are not directly comparable here. This is calculated by weighting the sugar level of individual products by their volume sales, so that high selling products with high sugar levels will push sales weighted average upwards. For yogurt, the reported baseline sales weighted average was 12.8g/100g, with a 20% reduction aim for 11.0g/100g product; the report suggests reformulation, reducing portion size and shifting portfolio of sales are all viable mechanisms to help achieve this.[37] While median sugar values are not directly comparable to sales weighted averages, our study suggests the organic (13.1g/100g), fruit (11.9g/100g) and flavoured (12.0g/100g) categories require the greatest changes. Children's yogurt and fromage frais products had a somewhat lower median of sugar 10.8g/100g, possibly meeting government guidelines (not clear as not sales weighted). However, given the recommendations that 4-6 year olds should have no more than 19g of sugar a day, a single pot of yogurt can contribute substantially to sugar intakes of

children. The sugar content of children's yogurts and fromage frais varied dramatically and there was no difference between the sugar contents of yogurts and fromage frais per 100g of product. However, as fromage frais has a much smaller serving size (median 47g vs 90g for yogurt), fromage frais products contained much less sugar than yogurt per serving (5.4 vs 9.2 g sugar/serving); with a single serving of yogurt on average delivering close to half of a child's daily maximal recommended intake of sugar.

Reformulation is likely to be challenging; beyond acting as a sweetener, added sugar in foods acts as a bulking, colouring and flavouring agent, and the use of sugar in foods is dictated by physical and chemical properties that are difficult to substitute.[44] In addition, in general consumers 'likeability' for yogurt is correlated positively with sweetness.[45] Lactic fermentation yields a sour taste that sugar as a flavouring attenuates. Consumers have been shown to prefer yogurt with 10-13% added sugar but may accept products with 7% added sugar while rejecting products with 5% or less added sugars as too sour.[45-47] In France where 40-50% of the market is for natural, unsweetened yogurt and fromage frais, nonetheless 50% of consumers will add a sweetener (caster sugar, jam or honey) before consuming.[48] When Saint-Eve and colleagues[48] precisely measured sugar added by 204 French subjects they found on average participants added 13.6 g of sugar to their yogurts, more than total content of many commercial sweetened yogurts. Participants underestimated how much sugar they were adding but still perceived their addition of sweetener to be the healthier option.[48] Notably, our work illustrates that natural/Greek yogurts have a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% vs range of 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) than all other categories. The observed glycaemic index (GI) of yogurts are generally much lower than predicted values calculated from their carbohydrate contents, with unsweetened yogurts having the lowest GI of all; this is contributed both to the fact that lactose has a low GI, but also because yogurts' protein content will reduce the glycemic response.[49] Adding a polyphenol rich jam or honey to a high protein unsweetened natural/Greek yogurt may well produce a more favourable glycemic response than one from sweetened yogurts, but this is likely to be highly variable among individuals, influenced by the meal consumed, their genetics and potentially their microbiome.[50] It has been proposed that there may be synergistic health benefits to consuming plain yogurt along with fruit, as a combination of pre- and probiotic food sources, but this has not been studied.[51] Even in the absence of a synergistic effect, consuming fruit with natural/Greek yogurt, rather than a sweetener like jam or honey, will have multiple nutritional benefits and is a reasonable public health message.

We had preconceived that low-fat yogurts would contain more sugar than their high-fat alternatives, in part because of a previous, short report from an American database analysis that showed low-fat products, including yogurts, contain more sugar than their higher fat counterparts.[39] In contrast, low-fat products surveyed here had significantly lower sugar in low-fat products (10.3 vs 13.1g/100g in high-fat). However, we note that although low-fat products did have less sugar on average, nonetheless

approximately 50% of low-fat products had between 10-20g sugar/100g. With an energy intake of 2000 kcal/day, 5% of added sugars is 25g, and a single serving of yogurt can easily provide greater than half of this. Nonetheless, low-fat products had lower energy, fat and sugar and were slightly higher in protein, in comparison to high-fat products. This profile appears consistent with current UK and US dietary guidelines that recommend low-fat dairy products out of concerns for obesity and cardiovascular disease. However, evidence is accumulating that high-fat rather than low-fat dairy is associated with a lower risk of obesity and diabetes.[21 23-25] A meta-analysis of observational studies found that the majority associated high-fat dairy consumption with lower adiposity.[21] Subsequent large cohort studies in Sweden (n=1782 males 40-60 years old)[23] and the US (n=18, 438 women ≥45 years old in the Women's Health Study)[24] have found high-fat dairy to be protective against developing central adiposity and becoming overweight or obese at follow up. Several studies suggest full fat milk is associated with reduced risk of overweight and obesity in children.[25 52 53] Food matrix effects likely also play a role, as can forage/feed influence the fatty acid profile of dairy.[54] However, these effects can be difficult to measure and data are limited comparing low-fat and high-fat yogurt specifically.

An added challenge for even an educated consumer is understanding that the total sugars on the label includes, in the case of yogurt, the intrinsic sugar lactose plus added sugars. UK labelling laws do not require the declaration of added sugars on nutrition labels and the sugar reduction guidelines focus on total sugars for this reason. Interestingly, although food companies have argued it is difficult to measure, the inclusion of added sugars (under total sugars) on food labels has been recently mandated in the US; companies have until 2020 or 2021 to implement depending on their size.[43] It will be interesting to see how food product companies and consumers navigate these changes. Our study highlighted other potential challenges and mixed messages for consumers, arising from marketing and packaging. Many products that were recommended for children's lunchboxes were very high sugar desserts (from jelly to dairy based) rather than yogurt or fromage frais. Retailers could play a positive role in promoting health here by establishing boundaries for inclusion in lunchbox recommendations. Furthermore, the portion sizes for children's yogurts varied enormously and were often identical to adult portion sizes. Equally there was little consistency in portion size in adult yogurts either, and particularly for larger pots (400-500g) of yogurt the serving size was either not given or was different from the equivalent smaller pot of yogurts (100-150g/serving). In multiple products with added plant stanols marketed for their cholesterol lowering merits, none would meet a low sugar claim and several were extremely high in sugar. In light of data linking high sugar consumption to high cholesterol levels,[55] arguably these products should be scrutinised for reformulation.

The study has some limitations. We would have liked to have included products sold outside the five major online supermarkets but this would have created difficulties in data collections and setting the boundary of inclusion. Ideally data collection should take place in as narrow a timeframe as possible and

we took only a month here. However, manufacturers may have made changes to products since this snapshot and it would be interesting to repeat the survey in future years. We felt that the comparison of own brand and national brand was useful but did not attempt to compare like-for-like. We did not incorporate analysis of price here; it would be interesting to assess if sugar or other nutrients relate to price; in a previous pilot study (data not shown) we measured weak, positive (more sugar, higher price), but inconsistent, correlations.

***Conclusion*s**

While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in nutrient content. In a comprehensive survey of the UK supermarket yogurt products we highlight here that the median sugar content of children's, fruit, flavoured, and organic yogurt categories were well above 10g/100g and represented >45% of total calories derived. Organic yogurts had the highest median sugar content (13.1g/100g). Notably, natural/Greek yogurts had a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% vs range of 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) contents than all other categories. While natural/Greek yogurts contained the least amount of sugars, their median total sugar (5.0g/100g, largely lactose) was markedly higher than the agreed allowance (3.8g/100g) for lactose. Low-fat products had less sugar and energy than high-fat yogurts. Within the children's category, fromage frais had higher protein and calcium contents/100g than yogurts and was marketed with smaller serving sizes. Less than 3% of children's products were low in sugar, and many products recommended for lunchboxes were high sugar desserts. We conclude, not all yogurts are as healthy as perhaps consumers perceive them, the majority are high in sugars and reformulation for the reduction of added sugars is warranted.

Contributors

JBM designed the study, analysed the data and wrote the manuscript. AH carried out the study, analysed the data and contributed to a preliminary draft. BF helped design and interpret the study, and revised the manuscript critically for important intellectual content.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests

None

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Tables

Table 1. Energy and nutrient contents of own and national brand yogurt products

	Own Brand			National Brand			
	N	Median	Range	N	Median	Range	*P* value*
Energy (kcal/100g)	267	96.0	46.0, 313.0	648	90.0	28.0, 445.0	0.0013
Fat (g/100g)	260	2.9	0.1, 19.8	625	2.6	0.0, 26.7	0.0019
Saturated Fat (g/100g)	263	1.9	0.1, 13.3	584	1.8	0.0, 19.0	0.0053
Carbohydrates (g/100g)	267	13.2	1.0, 29.8	648	12.3	2.1, 54.9	0.0002
Sugar (g/100g)	267	12.0	0.4, 27.0	644	11.4	1.5, 32.60	0.0003
Fibre (g/100g)	165	0.4	0.0, 2.0	244	0.3	0.0, 5.3	0.0034
Protein (g/100g)	267	4.0	0.4, 10.2	645	4.2	0.6, 11.0	0.0002
Salt (g/100g)	262	0.1	0.1, 0.3	632	0.1	0.0, 78.0	0.0001
Calcium (mg/100g)	57	122.0	71.3, 240.0	369	130.0	0.1, 283.0	0.1027

**P* value from two-tailed Mann-Whitney t test.

Table 2. Macronutrients (% energy) across yogurt categories.

		Fat		Carbohydrates (*% sugar*)		Protein	
	N	Median	Range	Median	Range	Median	Range
Children's	101	26.2[a]	19.9, 40.8	52.0[a] *(45.5)*	25.4, 57.9	20.0[a]	13.1, 40.5
Dairy Alt.	38	30.2[a]	21.9, 86.3	50.8[a,b] *(48.4)*	7.1, 63.5	18.8[a]	2.4, 40.0
Dessert	161	32.6[a]	0, 63.1	55.0[c] (46.3)	29.0, 100	10.8[b]	0.0, 34.9
Drinks	70	17.1[b]	0.0, 54.8	62.4[c] (52.5)	25.6, 95.2	15.8[a]	7.9, 40.0
Flavoured	79	31.7[a]	0.0, 53.5	52.2[a,b] (45.8)	26.4, 69.6	14.7[a]	0.0, 70.0
Fruit	311	16.8[b]	0.0, 53.5	56.7[c] (52.8)	32.5, 78.1	18.1[a]	7.6, 61.5
Natural/Greek	61	25.9[a]	0.0, 75	34.7[b] (30.4)	32.5, 61.3	32.3[c]	11.4, 72.3
Organic	71	33.4[a]	0.0, 69.8	48.5[a,b] (46.7)	32.5, 73.5	17.5[a]	0.3, 56.3

[a,b,c]Median values within a column with unlike superscript letters were significantly different (P<0.0001) by Kruskal-Walis and Dunn's multiple comparison tests.

Table 3. Sugar and fibre in Fruit, Flavoured and Natural/Greek yogurt products.

	Fruit			Flavoured			Natural/Greek		
	N	Median	Range	N	Median	Range	N	Median	Range
Sugar (g/100g)	305	11.9[a]	4.6, 21.3	79	12.0[a]	0.1,18.8	60	5[b]	1.6, 9.5
Fibre (g/100g)	170	0.3[a]	0.0, 2.4	42	0[b]	0.0, 0.9	26	0[b]	0.0, 0.9

[a,b]Median values within a row with unlike superscript letters were significantly different (P<0.0001) by Kruskal-Walis and Dunn's multiple comparison

Figure Legends

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

Figure 2. Nutrient and energy contents of UK yogurt products across categories. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations[2] for nutrition claims for low sugar **A** and low fat **B**.

Figure 3. Nutrients compared across the high (n=383) and low (n=530) fat categories. **A** Sugar. **B** Fat. **C** Protein. **D** Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

References

1. Thorning TK, Bertram HC, Bonjour JP, et al. Whole dairy matrix or single nutrients in assessment of health effects: current evidence and knowledge gaps. *Am J Clin Nutr* 2017;105:1033-45. doi: 10.3945/ajcn.116.151548
2. European Parliament Council of the European Union. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union* 2006:L 404/9.
3. Morelli L. Yogurt, living cultures, and gut health. *Am J Clin Nutr* 2014;99:1248s-50s. doi: 10.3945/ajcn.113.073072
4. Ashraf R, Shah NP. Immune system stimulation by probiotic microorganisms. *Crit Rev Food Sci Nutr* 2014;54:938-56. doi: 10.1080/10408398.2011.619671
5. European Food Safety Authority. Scientific Opinion on the substantiation of health claims related to live yoghurt cultures and improved lactose digestion. 2010;8:1763.
6. Marette A, Picard-Deland E. Yogurt consumption and impact on health: focus on children and cardiometabolic risk. *Am J Clin Nutr* 2014;99:1243s-7s. doi: 10.3945/ajcn.113.073379
7. Cormier H, Thifault E, Garneau V, et al. Association between yogurt consumption, dietary patterns, and cardio-metabolic risk factors. *Eur J Nutr* 2016;55:577-87. doi: 10.1007/s00394-015-0878-1
8. Zhu Y, Wang H, Hollis JH, et al. The associations between yogurt consumption, diet quality, and metabolic profiles in children in the USA. *Eur J Nutr* 2015;54:543-50. doi: 10.1007/s00394-014-0735-7
9. Wang H, Livingston KA, Fox CS, et al. Yogurt consumption is associated with better diet quality and metabolic profile in American men and women. *Nutr Res* 2013;33:18-26. doi: 10.1016/j.nutres.2012.11.009
10. Aune D, Norat T, Romundstad P, et al. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. *Am J Clin Nutr* 2013;98:1066-83. doi: 10.3945/ajcn.113.059030
11. Gao D, Ning N, Wang C, et al. Dairy products consumption and risk of type 2 diabetes: systematic review and dose-response meta-analysis. *PLoS One* 2013;8:e73965. doi: 10.1371/journal.pone.0073965
12. Chen M, Sun Q, Giovannucci E, et al. Dairy consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *BMC Med* 2014;12:215. doi: 10.1186/s12916-014-0215-1
13. Gijsbers L, Ding EL, Malik VS, et al. Consumption of dairy foods and diabetes incidence: a dose-response meta-analysis of observational studies. *Am J Clin Nutr* 2016;103:1111-24. doi: 10.3945/ajcn.115.123216
14. Tremblay A, Panahi S. Yogurt Consumption as a Signature of a Healthy Diet and Lifestyle. *J Nutr* 2017;147:1476s-80s. doi: 10.3945/jn.116.245522
15. Wu L, Sun D. Consumption of Yogurt and the Incident Risk of Cardiovascular Disease: A Meta-Analysis of Nine Cohort Studies. *Nutrients* 2017;9 doi: 10.3390/nu9030315
16. Guo J, Astrup A, Lovegrove JA, et al. Milk and dairy consumption and risk of cardiovascular diseases and all-cause mortality: dose-response meta-analysis of prospective cohort studies. *EurJ Epidemiol* 2017;32:269-87. doi: 10.1007/s10654-017-0243-1
17. Sayon-Orea C, Martinez-Gonzalez MA, Ruiz-Canela M, et al. Associations between Yogurt Consumption and Weight Gain and Risk of Obesity and Metabolic Syndrome: A Systematic Review. *Adv Nutr* 2017;8:146s-54s. doi: 10.3945/an.115.011536
18. Schwingshackl L, Hoffmann G, Schwedhelm C, et al. Consumption of Dairy Products in Relation to Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Cohort Studies. *PLoS One* 2016;11:e0157461. doi: 10.1371/journal.pone.0157461
19. Santiago S, Sayon-Orea C, Babio N, et al. Yogurt consumption and abdominal obesity reversion in the PREDIMED study. *Nutr Metab Cardiovasc Dis* 2016;26:468-75. doi: 10.1016/j.numecd.2015.11.012

20. Guasch-Ferre M, Becerra-Tomas N, Ruiz-Canela M, et al. Total and subtypes of dietary fat intake and risk of type 2 diabetes mellitus in the Prevencion con Dieta Mediterranea (PREDIMED) study. *Am J Clin Nutr* 2017;105:723-35. doi: 10.3945/ajcn.116.142034
21. Kratz M, Baars T, Guyenet S. The relationship between high-fat dairy consumption and obesity, cardiovascular, and metabolic disease. *Eur J Nutr* 2013;52:1-24. doi: 10.1007/s00394-012-0418-1
22. Weaver CM. How sound is the science behind the dietary recommendations for dairy? *Am J Clin Nutr* 2014;99:1217s-22s. doi: 10.3945/ajcn.113.073007
23. Holmberg S, Thelin A. High dairy fat intake related to less central obesity: a male cohort study with 12 years' follow-up. *Scand J Prim Health Care* 2013;31:89-94. doi: 10.3109/02813432.2012.757070
24. Rautiainen S, Wang L, Lee IM, et al. Dairy consumption in association with weight change and risk of becoming overweight or obese in middle-aged and older women: a prospective cohort study. *Am J Clin Nutr* 2016;103:979-88. doi: 10.3945/ajcn.115.118406
25. Beck AL, Heyman M, Chao C, et al. Full fat milk consumption protects against severe childhood obesity in Latinos. *Prev Med Rep* 2017;8:1-5. doi: 10.1016/j.pmedr.2017.07.005
26. Chowdhury R, Warnakula S, Kunutsor S, et al. Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis. *Ann Intern Med* 2014;160:398-406. doi: 10.7326/m13-1788
27. Williams EB, Hooper B, Spiro A, et al. The contribution of yogurt to nutrient intakes across the life course. *Nutr Bull* 2015;40:9-32. doi: 10.1111/nbu.12130
28. Rizzoli R. Dairy products, yogurts, and bone health. *Am J Clin Nutr* 2014;99:1256s-62s. doi: 10.3945/ajcn.113.073056
29. Salas MM, Nascimento GG, Vargas-Ferreira F, et al. Diet influenced tooth erosion prevalence in children and adolescents: Results of a meta-analysis and meta-regression. *J Dent* 2015;43:865-75. doi: 10.1016/j.jdent.2015.05.012
30. Lythgoe A, Roberts C, Madden AM, et al. Marketing foods to children: a comparison of nutrient content between children's and non-children's products. *Public Health Nutr* 2013;16:2221-30. doi: 10.1017/s1368980013000943
31. Walker RW, Goran MI. Laboratory Determined Sugar Content and Composition of Commercial Infant Formulas, Baby Foods and Common Grocery Items Targeted to Children. *Nutrients* 2015;7:5850-67. doi: 10.3390/nu7075254
32. Azais-Braesco V, Sluik D, Maillot M, et al. A review of total & added sugar intakes and dietary sources in Europe. *Nutr J* 2017;16:6. doi: 10.1186/s12937-016-0225-2
33. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. *J Dent Res* 2014;93:8-18. doi: 10.1177/0022034513508954
34. Moore JB, Fielding BA. Sugar and metabolic health: is there still a debate? *Curr Opin Clin Nutr Metab Care* 2016;19:303-09. doi: 10.1097/MCO.0000000000000289
35. National Statistics. Statistics on Obesity, Physical Activity and Diet, England 2017. 2017
36. Scientific Advisory Committee on Nutrition. Carbohydrates and Health. London: The Stationery Office, 2015.
37. Public Health England. Sugar reduction: Achieving the 20%, 2017.
38. Kantar Worldpanel. Grocery market Share for Great Britain 2017 [Available from: https://www.kantarworldpanel.com/en/grocery-market-share/great-britain accessed November 24th, 2017
39. Nguyen PK, Lin S, Heidenreich P. A systematic comparison of sugar content in low-fat vs regular versions of food. *Nutr Diabetes* 2016;6:e193. doi: 10.1038/nutd.2015.43
40. Public Health England. National Dental Epidemiology Programme for England: Oral health survey of five-year-old children 2012 A report on the prevalence and severity of dental decay. 2012
41. Royal College of Surgeons: Faculty of Dental Surgery. The state of children's oral health in England. 2015
42. Health and Social Care Information Centre. Statistics on Obesity, Physical Activity and Diet: England 2017 2017 [Available from: https://www.gov.uk/government/statistics/statistics-on-obesity-physical-activity-and-diet-england-2017.

43. Food and Drug Administration. Food Labeling: Revision of the Nutrition and Supplement Facts Labels. *Federal Register*;81:Docket No. FDA–2012–N–1210.
44. Chinachoti P. Carbohydrates: functionality in foods. *Am J Clin Nutr* 1995;61:922s-29s.
45. Bayarri S, Carbonell I, Barrios EX, et al. Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *Int Dairy J* 2011;21:111-18. doi: https://doi.org/10.1016/j.idairyj.2010.09.002
46. Johansen SB, Næs T, Øyaas J, et al. Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Qual Prefer* 2010;21:13-21. doi: https://doi.org/10.1016/j.foodqual.2009.07.003
47. Chollet M, Gille D, Schmid A, et al. Acceptance of sugar reduction in flavored yogurt. *J Dairy Sci* 2013;96:5501-11. doi: 10.3168/jds.2013-6610
48. Saint-Eve A, Leclercq H, Berthelo S, et al. How much sugar do consumers add to plain yogurts? Insights from a study examining French consumer behavior and self-reported habits. *Appetite* 2016;99:277-84. doi: 10.1016/j.appet.2016.01.032
49. Wolever TM. Yogurt Is a Low-Glycemic Index Food. *J Nutr* 2017;147:1462s-67s. doi: 10.3945/jn.116.240770
50. Zeevi D, Korem T, Zmora N, et al. Personalized Nutrition by Prediction of Glycemic Responses. *Cell* 2015;163:1079-94. doi: 10.1016/j.cell.2015.11.001
51. Fernandez MA, Marette A. Potential Health Benefits of Combining Yogurt and Fruits Based on Their Probiotic and Prebiotic Properties. *Adv Nutr* 2017;8:155s-64s. doi: 10.3945/an.115.011114
52. Scharf RJ, Demmer RT, DeBoer MD. Longitudinal evaluation of milk type consumed and weight status in preschoolers. *Arch Dis Child* 2013;98:335-40. doi: 10.1136/archdischild-2012-302941
53. Bigornia SJ, LaValley MP, Moore LL, et al. Dairy intakes at age 10 years do not adversely affect risk of excess adiposity at 13 years. *J Nutr* 2014;144:1081-90. doi: 10.3945/jn.113.183640
54. Givens DI, Soedamah-Muthu SS. Dairy fat: does it increase or reduce the risk of cardiovascular disease? *Am J Clin Nutr* 2016;104:1191-92. doi: 10.3945/ajcn.116.144766
55. Te Morenga LA, Howatson AJ, Jones RM, et al. Dietary sugars and cardiometabolic risk: systematic review and meta-analyses of randomized controlled trials of the effects on blood pressure and lipids. *Am J Clin Nutr* 2014;100:65-79. doi: 10.3945/ajcn.113.081521

Figure 1

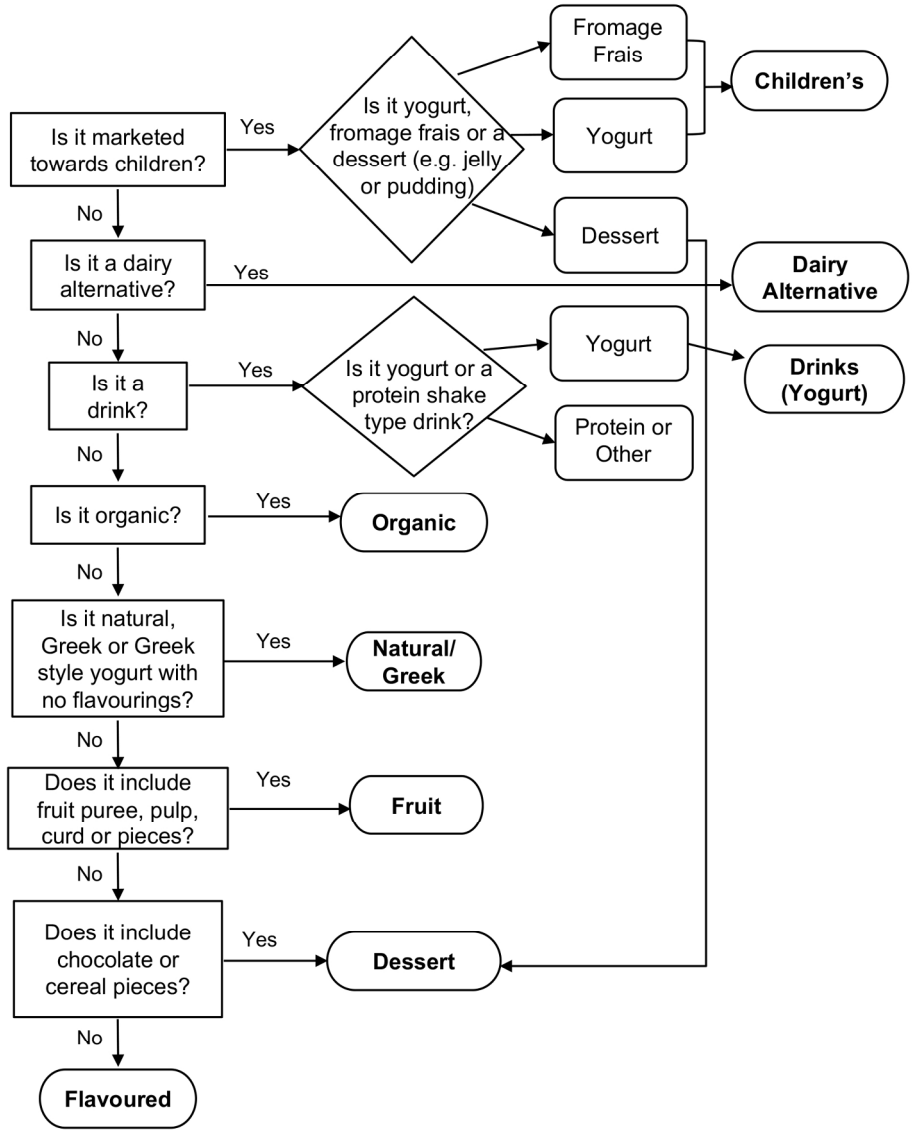

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

163x207mm (300 x 300 DPI)

Figure 2

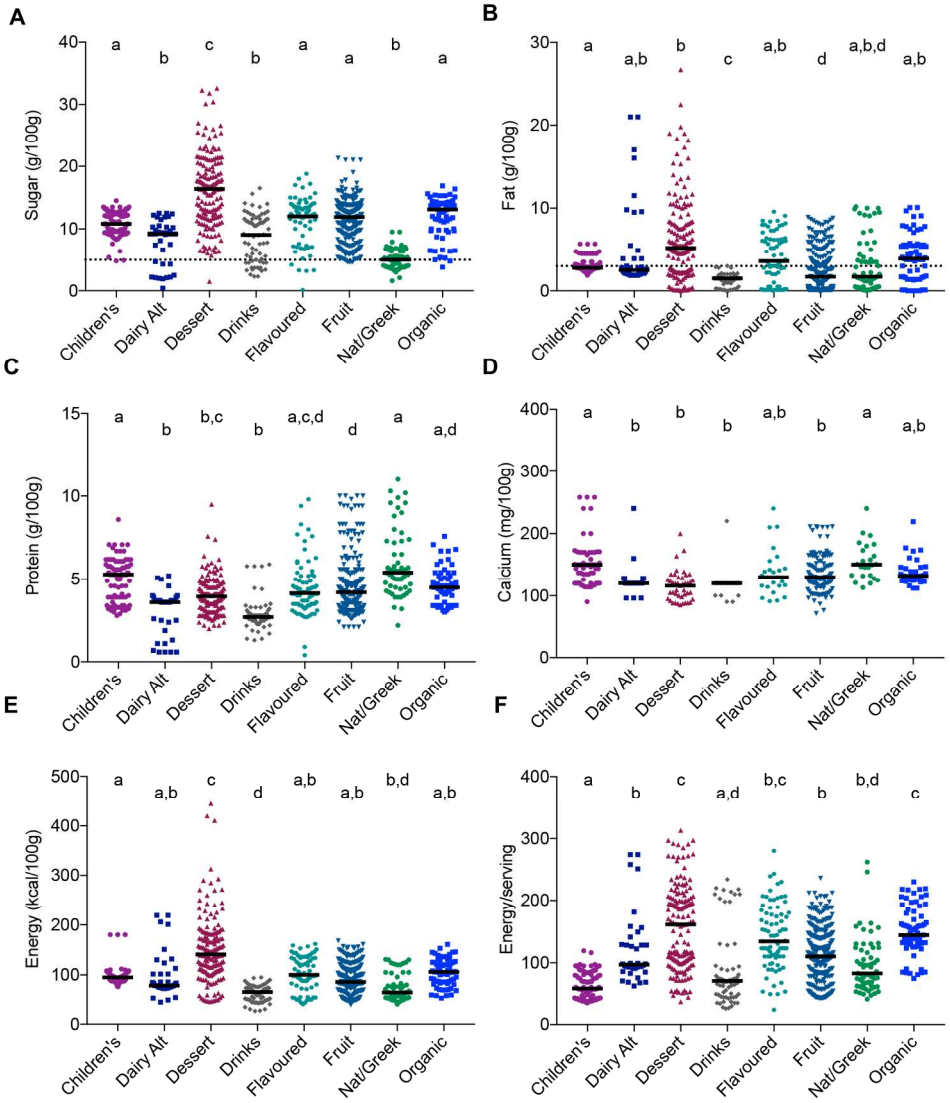

Figure 2. Nutrient and energy contents of UK yogurt products across categories. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations2 for nutrition claims for low sugar A and low fat B.

166x205mm (300 x 300 DPI)

Figure 3

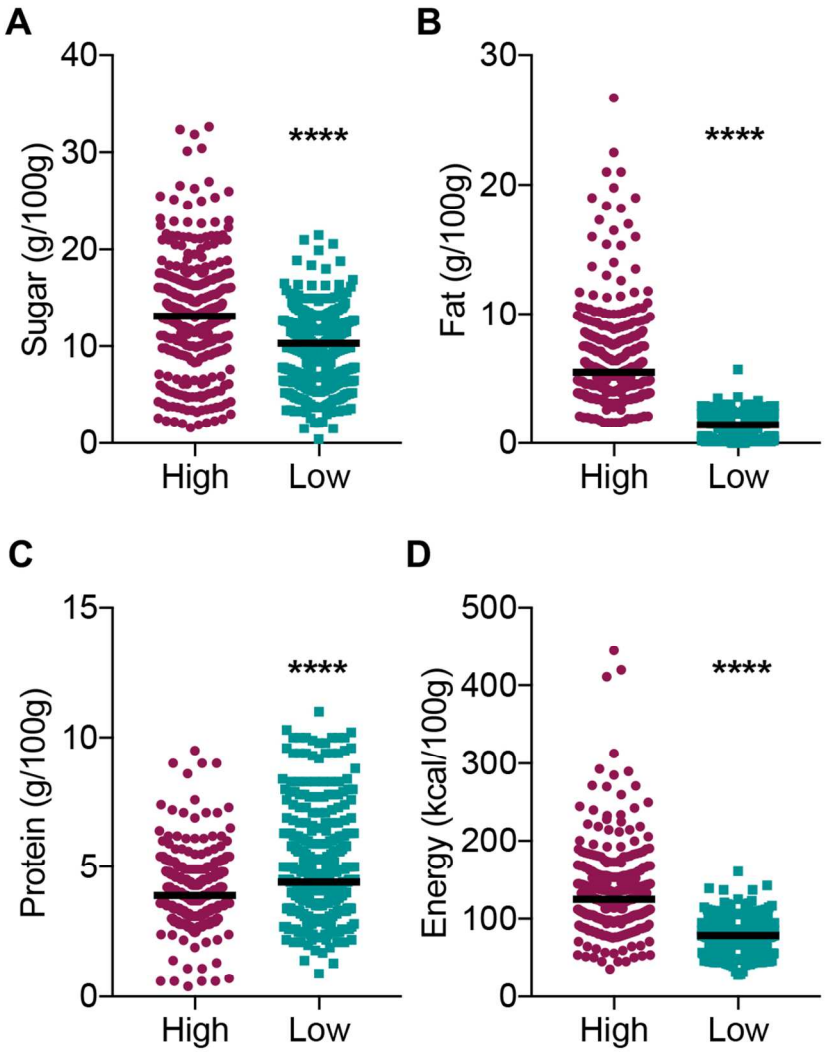

Figure 3. Nutrients compared across the high (n=383) and low (n=530) fat categories. A Sugar. B Fat. C Protein. D Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

93x126mm (300 x 300 DPI)

Figure 4

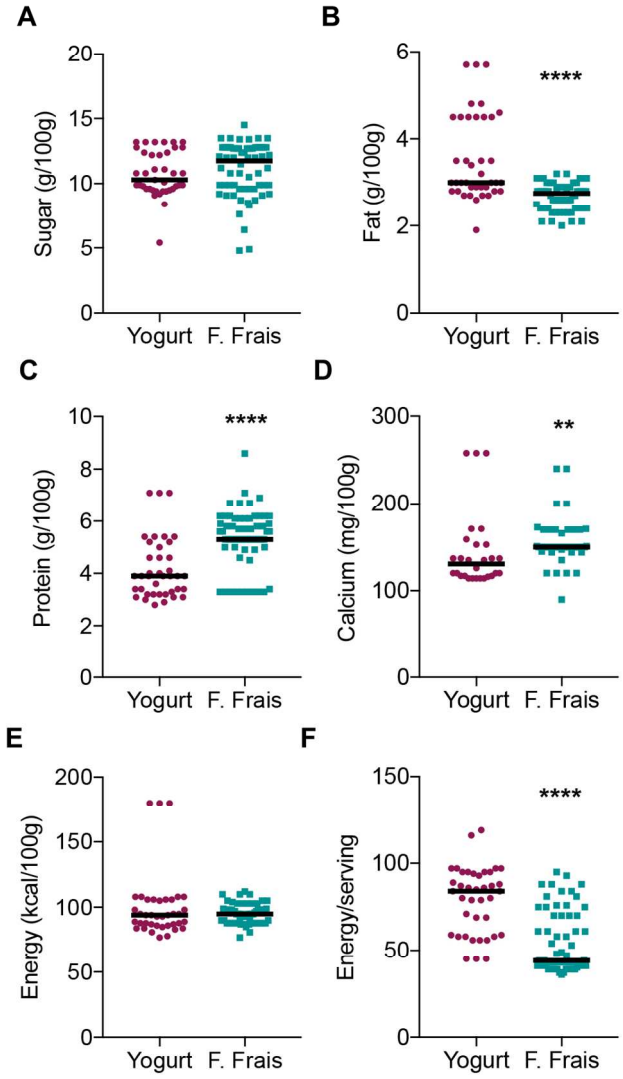

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

96x170mm (300 x 300 DPI)

BMJ Open

An evaluation of the nutrient contents of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-021387.R1
Article Type:	Research
Date Submitted by the Author:	04-Apr-2018
Complete List of Authors:	Moore, Bernadette; University of Leeds , School of Food Science and Nutrition; University of Surrey Horti, Annabelle; University of Leeds , School of Food Science and Nutrition Fielding, Barbara; University of Surrey, Department of Nutritional Sciences
Primary Subject Heading:	Nutrition and metabolism
Secondary Subject Heading:	Dentistry and oral medicine, Diabetes and endocrinology, General practice / Family practice, Health policy, Paediatrics
Keywords:	Yogurt, Sugar, Children, Obesity

TITLE PAGE

Title

An evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Author names

J. Bernadette Moore[1,2], Annabelle Horti[1] and Barbara A. Fielding[2]

Author affiliations

[1]School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK

[2]Department of Nutritional Sciences, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, UK

Corresponding author

Dr. J. Bernadette Moore

University of Leeds

School of Food Science and Nutrition

Leeds

LS2 9JT, UK

Tel: +44 (0) 113 343 9900

Email: j.b.moore@leeds.ac.uk

Running title

Nutrient content of yogurts in the UK

Keywords

Yogurt, Sugar, Children, Obesity

Abstract

Objectives: To comprehensively survey the sugar and nutrient contents of yogurt products available in UK supermarkets across categories, in particular those marketed to children.

Design: A cross sectional survey of yogurt products available in the UK's supermarkets in November 2016.

Methods: Data were collected from five major online UK supermarkets and a process flow strategy was used to place yogurts into eight categories: children's, dairy alternatives, dessert, drinks, fruit, flavoured, natural/Greek style and organic. A comprehensive database of product information for 915 unique products was created and analysed.

Results: The sugar, fat, protein, calcium and energy contents were highly variable across categories, and the ranges were extremely broad. Although lower than the dessert category, the median[range] sugar content of children's (10.8g/100g [4.8, 14.5]), fruit (11.9g/100g [4.6, 21.3]), flavoured (12.0g/100g [0.1, 18.8]), and organic (13.1g/100g [3.8, 16.9]), yogurt products were all well above 10g/100g, and represented >45% of total energy. Only 3 of 101 children's yogurt and fromage frais products surveyed were low in sugar (</= 5g/100g). Natural/Greek yogurts had dramatically lower total sugar contents (5.0g/100g [1.6, 9.5], largely lactose) than all other categories. Low-fat products had less sugar and energy than high-fat yogurts. Within the children's category, fromage frais had higher protein (5.3g/100g [3.3, 8.6] vs. 3.2 [2.8, 7.1]; P <0.0001) and calcium contents (150mg/100g [90, 240] vs. 130.5 mg/100g [114, 258]; P= 0.0015) than yogurts.

Conclusions: While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in nutrient contents. Not all yogurts are as healthy as perhaps consumers perceive them; in particular the majority are high in sugars and reformulation for the reduction of added sugars is warranted.

Strengths and limitations of this study

- This work comprehensively examines for the first time the energy and nutrient (sugar, fat, protein, calcium) contents of yogurt products available in five major UK supermarkets with an online presence covering 75% of the UK grocery market share.
- The results of 915 products are individually presented in categories, allowing differences of nutrients between categories, and ranges within categories to be seen. This highlights the very high content of sugar in most yogurt product categories, in particular products marketed to children and organic yogurts.
- There are some limitations in the study design. For example, the a priori categories chosen, meant that there were some overlaps between different categories, but this can be seen from a process flow diagram. The samples did not include less well-known yogurt brands, produced or sold by small-scale local food manufacturers, or yogurts sold in dessert shops. The nutrient information provided by manufacturers and supermarkets online may not always be accurate or up-to-date.

Introduction

The association between dairy foods and disease risk has often been contradictory, likely due to inherent diversity in the nutrient contents and food matrices of different dairy products.[1] Yogurt is the product of milk fermented with the lactic cultures *Streptococcus thermophiles* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, which can be enhanced with other probiotic cultures such as *Lactobacillus acidophilus* and *Bifidobacterium bifidus*.[2] Consumption of fermented dairy products has long been considered to be beneficial to digestive and overall health.[3] The beneficial probiotic and immune regulatory effects of yogurts underpin their recommendation as a healthy food for babies and children.[4] Multiple regulatory bodies, including the European Food Safety Authority, have approved health claims related to yogurt consumption and reduction in symptoms caused by lactose maldigestion.[5] In addition to probiotics, yogurt is a good source of protein, calcium, iodine and vitamin $B_{12,}$ and its consumption has been associated with lower risk of obesity and cardiometabolic risk in both children and adults.[6 7]

Evidence is accumulating that frequent yogurt consumption may be associated with healthier metabolic profiles in both children and adults.[8 9] In adults, increased yogurt consumption has been associated with lower levels of circulating triglycerides, glucose and lower systolic blood pressure;[9] and several recent meta-analyses have demonstrated that increased yogurt consumption is inversely associated with the risk of developing type 2 diabetes.[10-13] Notably, across three large American cohort studies (the Health Professionals Follow-Up Study and the Nurses' Health Studies I and II) in >190,000 adults and >30 years follow-up; while there was no effect of dairy on incident type 2 diabetes (T2D), yogurt intake specifically was inversely associated with T2D risk across the three cohorts with a pooled hazard ratio of 0.83 (0.75, 0.92) for one serving/day.[12] Although confounders were statistically accounted for, an acknowledged limitation to these epidemiology studies is the evidence that yogurt is a general marker of healthy dietary habits.[9 14] Data are more equivocal regarding yogurt consumption and cardiovascular disease risk, although one study suggested a possible lowered risk at higher consumption levels of yogurt (>200g/d),[15] a more recent and comprehensive meta-analysis showed no benefit.[16] High quality and adequately powered randomised controlled trials are lacking however.

Prospective cohort studies have, in general, shown inverse associations between yogurt consumption and changes in waist circumference, weight and risk of overweight or obesity; with some inconsistencies between studies.[17,18] More recently, in an elderly Italian population cohort of >4,000 at high cardiovascular risk, consumption of whole-fat yogurt (but not total yogurt consumption) was associated with changes in waist circumference and higher probability for reversion of abdominal obesity and lower risk of diabetes.[19,20] This is in line with a previous systematic review of observational studies on the relationship between dairy fat, obesity, and cardiometabolic disease; in 11 of 16 studies included in the review, high-fat dairy intake was inversely associated with measures of adiposity.[21] While dietary

guidelines vary by region, most countries make dietary recommendations for the consumption of dairy products because of the strong evidence for role of dairy products in meeting nutrient intake requirements.[22] In both the US and UK, current dietary guidelines recommend low-fat and low sugar dairy products because of obesity related concerns; however, a growing number of recent studies suggest that high-fat dairy consumption is associated with a lower risk of obesity and diabetes[21 23-25] Large cohort studies in Sweden (n=1782 males 40-60 years old)[23] and the US (n=18, 438 women ≥45 years old in the Women's Health Study)[24] have found high-fat dairy to be protective against developing central adiposity and becoming overweight or obese at follow up. These data have fed into ongoing wider debate regarding dietary guidance related to fat, refined sugars, and cardiovascular disease risk.[26]

In the UK, on average, children consume more yogurt than adults, and children under three years of age have the highest intakes.[27] Yogurt contributes a significant percentage of the daily RNI of key nutrients to babies and children up to 10 years of age, providing for example: 10-19% calcium, 11-20% phosphorus, 10-21% riboflavin and 17-54% vitamin B_{12}.[27] Yogurts are often recommended to be part of children's diets due to their high calcium content and its positive effect on bone development.[28] Calcium also has a positive effect on teeth and high intakes of milk and yogurt products in multiple studies have been associated with reduced tooth erosion.[29] However, although there is good evidence to suggest that yogurt can be beneficial to health, products on the market may vary widely in sugar content and yogurt marketed specifically to children may be higher in added sugars (see Table 1 for definitions of sugars).[30] [31] Dairy is a significant contributor to the intakes of added sugars by children and adults.[32] Diets high in added sugars are now unequivocally linked to obesity and dental caries, prompting the World Health Organisation and other regulatory bodies in updating dietary guidelines to strongly advocate for restricting added sugar consumption to less than 10% of total energy.[33] [34] With an alarming 58% of women and 68% of men along with 1 in 3 of UK children aged 10-11 years overweight or obese in 2015,[35] the UK's guidelines more stringently recommended the restriction of dietary sugars to less than 5% of total daily energy.[36] As part of a plan to combat childhood obesity, the UK government has implemented an industry soft drinks levy that will take effect in April 2018 and commissioned a structured programme of monitored sugar reduction as part of wider reformulation tackling calories, salt and saturated fat.[37] The initial focus was on the top 9 food categories (after soft drinks and fruit juices and smoothies) that contribute the most to children's sugar intakes. These are: chocolate, confectionery, biscuits, breakfast cereals, cakes, morning goods (such as croissants, buns and waffles), ice cream, yogurt and sweet spreads/sauces. Yogurt was one of the products identified and highlighted for a 20% reduction of sugar by 2020, with guidelines given for energy per portion size of 120kcal sales weighted average; 175kcal maximum per portion and an allowance made for lactose (3.8g/100g).[37]

In this context then, the aims of this work were to perform a comprehensive survey of yogurt products within the major UK supermarkets, in order to identify products marketed at children and to evaluate their nutrient contents, in particular sugars, compared with other categories.

Experimental methods

Data collection

Data were collected from five major UK online supermarkets (Asda, Morrisons, Sainsbury's, Tesco and Waitrose) that account for 75% of the UK grocery market share.[38] Websites were searched from 07/10/16-16/11/16 using 'yogurt' or 'yoghurt' as a search term (in 4 of 5 supermarkets the same number of products were returned). After considering the product groupings commonly used by online supermarkets, eight categories (children's, dairy alternatives, dessert, drinks, flavoured, fruit, natural/Greek, organic) and a systematic process flow strategy for product placement (Fig. 1) was decided upon *a priori*. For example, soya-based yogurts were placed in the 'dairy alternative' category, whereas Greek style yogurts with added honey were in the 'flavoured' category. In the case of natural yogurts, if organic, they went in organic category. In scrutinising the children's category, the ingredients lists were used to evaluate presence or absence of yogurt or fromage frais cultures. The dessert category contained both yogurt-based and other products (eg. jellies and puddings-i.e. chocolate mousse, crème caramels) that contained no cultures but had come under the supermarket category of yogurts. 'Fruit' was defined liberally, for example many products were made with either curd or purees and for lemon products in particular, often with juice. For the classification of high and low-fat, the cut-offs defined by EU regulations were used; where a low-fat product is defined by a maximum of 3g of fat/100g or 1.5g/100ml for drinks; and low sugar is defined by a maximum of 5 g total sugars/100g.[2] Data were screened for duplicates and a non-redundant database of product information was created that included: nutrient information, serving size, size of pack, claims on pack and ingredients. Nutrient information was confirmed from the brand's own website where possible and a subset were examined during in-store visits. Information on macronutrients, including energy, fat, saturated fat, carbohydrates, sugar, fibre and protein were collected, as well as any information on micronutrients. Data for macronutrients have been expressed as g/100g product as well as % energy, as both are needed to evaluate its nutritional merits; e.g. a yogurt with a lower energy content per 100g may have a higher % energy from sugar than a product with a higher energy content. All data were independently double-checked and 5% of all entries were randomly selected and verified.

Data analysis

Pivot tables in Excel were used for building and manipulating the product database and statistical analyses were done utilising Graph Pad Prism 7.0c. Normality was examined using the D'Agostino-Pearson omnibus normality test and comparisons across all categories were made using the non-parametric Kruskal-Wallis test with Dunns multiple comparisons. For comparisons of two categories,

again in not observing normal distributions, the non-parametric, two tailed Mann-Whitney test was applied.

Patient and Public Involvement

Patients and the public were not involved in this research.

Results

Nine hundred and fifteen products available online during the period of the survey were included in the analysis. Sixty-five products were available in all five supermarkets, although national branded products dominated the products available (n=648 national vs n=267 own brand products). The sugar content varied enormously both within and across yogurt categories (Fig. 2a). With the exception of the natural/Greek category, the median sugar contents of all categories were well above the 5g/100g maximal threshold considered 'low sugar' for nutrition claims.[2] Products within the dessert category, unsurprisingly, had the highest median and broadest [range] of total sugar at 16.4g/100g [1.5, 32.6] (Fig. 2a). However, the children's, flavoured, fruit and organic categories all had relatively high, and similar, median sugar contents ranging from 10.8g/100g (children's) to 13.1g/100g (organic). As the natural/Greek category contained no added sweeteners, it had the lowest median amount of sugars per product (5g/100g [1.6, 9.5]). These sugars will be ~80% lactose (Table 1), but notably the range observed here suggests many products will have higher than the allowance of 3.8g/100g specified for lactose in the guidelines. The dairy alternatives and drinks categories also had sugar medians higher than the 5g/100g threshold, nonetheless these were still significantly lower that the children's, flavoured, fruit and organic categories with median[ranges] of 9.2g/100g [0.4, 12.5] and 9.1g/100g [2.3, 16.5] (Fig. 2a).

Somewhat in contrast to sugar, as seen in Fig. 2b, many yogurt categories (children's, dairy alternative, drinks, fruit, natural/Greek) had median levels of fat lower than the thresholds considered 'low-fat' for nutrition claims (3g/100g for food and 1.5g/100mL for drinks).[2] While flavoured and organic yogurts were just over this threshold with medians for fat of 3.6g/100g [0, 9.6] and 3.9g/100g [0, 10.1], respectively; the dessert category contained the highest median amount of fat and had the broadest range at 5.2g/100g [0, 26.7] (Fig. 2b). The drinks category had the lowest median fat contents at 1.5g/100g [0, 3.0], but the fruit and natural/Greek categories were also relatively low with medians of 1.7[0, 8.9] and 1.7[0, 10.1]g/100g respectively (Fig. 2b).

The natural/Greek and the children's categories had the highest median protein contents at 5.4[2.2, 11.0] and 5.3[2.8, 8.6]g/100g yogurt (Fig 2c). The higher protein median for the children's category was influenced, as expanded on below, to a significant degree by a large percentage of higher protein fromage frais products. The dessert, fruit, flavoured and organic categories had very similar median protein contents 4.0-4.5 g/100g, whereas drinks and dairy alternatives contained the least amount of protein at 2.7 [1.3, 5.9] and 3.6[0.6, 5.2]g/100g (Fig 2c). Calcium values were less frequently reported, but median values between yogurt categories were broadly similar ranging from 116-150 mg/100g (Fig. 2d). Mimicking protein, the natural/Greek and the children's categories had the highest calcium contents. The dessert category, again not surprisingly, contained significantly more energy/100g (Fig. 2e) and more energy/serving (Fig. 2f) than any other category. Although the children's category had the least

energy/serving (Fig. 2f), this was clearly because of smaller serving sizes. When expressed as kcal/100g, the median energy of children's yogurts was similar to products in the dairy alternative, flavoured, fruit and organic categories (ranging from 79-100g/100g), and these were significantly higher than the median (65g/100g) of the natural/Greek category (Fig. 2e).

In examining the macronutrient content (as %energy) of yogurts across categories, it was clear that the majority of carbohydrates in yogurt products are derived from sugars (Table 2). Carbohydrate content ranged from the extremes of 34.7% (natural/Greek) to 62.4% (drinks) of energy content, but all other categories were tightly bunched at 48.5-56.7% carbohydrate content. The natural/Greek category was significantly higher in protein (32.3%) than any other category, while the dessert category had the least amount of protein (10.8%) and highest percentage of fat (32.6%; Table 2). Although fruit and flavoured yogurts had very similar sugar contents, fruit yogurts contained small, but appreciably more, amounts of fibre compared to flavoured or natural/Greek yogurts (Table 3).

It has previously been reported from an analysis of a US database that low-fat products, including yogurts, contain more sugar than their higher fat counterparts.[39] However, in comparing high (n=383) and low-fat (n=530) yogurt products here, we did not observe this. High-fat yogurt products had significantly higher amounts of sugar in comparison to low-fat yogurts (13.1[1.6, 32.6] versus 10.3[0.4, 21.5]g/100g; Fig 3a), and much higher median and broader range of fat (5.5[1.6, 26.7] versus 1.4[0, 5.7]g/100g; Fig 3b). Low-fat yogurts contained more protein than high-fat products (4.4[0.9, 11.0] versus 3.9[0.4, 9.5]g/100g; Fig 3c), and much lower energy per 100g (79[28.0, 161.0] versus 125[36, 445]g/100g; Fig 3d).

While fromage frais is also a fresh lactic fermented milk product, it is made with cheese cultures rather than yogurt cultures. In most of the categories, less than 5% of products were fromage frais and were not separated out. However, in the children's category, fromage frais dominated, representing 60% of products (n=62 vs n=39 yogurts) so their nutrient contents were assessed separately (Fig. 4). While there was no difference in the sugar content of children's yogurt and fromage frais (Fig. 4a); fromage frais products had lower fat (Fig. 4b; $P<0.0001$), higher protein (Fig. 4c; $P<0.0001$) and higher calcium (Fig. 4d; $P<0.01$) compared to children's yogurts. Although there was no difference in energy/100g (Fig. 4e), the energy/serving was significantly lower for fromage frais (Fig. 4f; $P<0.0001$) reflecting its often smaller serving size.

Discussion

We have comprehensively evaluated yogurt products sold in the major UK supermarkets in November 2016, examining nutrient contents across categories, including those products marketed to children. Our results highlight that the total sugar content of yogurts is high in all categories, with the exception of the natural/Greek category. Very few products qualified for a 'low sugar' claim (less than 5g/100g) and almost none in the children's category. This is concerning given both the continued increase in childhood obesity and prevalence of tooth decay among children starting school (28%).[40] Tooth extractions are shockingly the primary reason children aged 5-9 are admitted to hospital (with general anaesthetic) in the UK.[41] Moreover, in 2015/16 more than 1 in 5 children in Reception (age 4-6), and 1 in 3 children in Year 6 (age 10-12) were measured as obese or overweight in England.[42] While yogurt may be less of a concern than soft drinks and fruit juices, the chief sources of added sugars in both children and adult's diets; what is worrisome is that yogurt, as a perceived 'healthy food', may be an unrecognised source of added sugars in the diet. Indeed, a potentially surprising observation from our data was that, after the dessert category, it was organic yogurts that had the highest median sugar content (13.1g/100g). While the organic label refers to production, the well documented 'health halo' effect means that consumers most often underestimate the caloric content and perceive the nutritional contents of organic products, including yogurts, more favourably.[43]

An added challenge for even an educated consumer is understanding that the total sugars on the label includes, in the case of yogurt, the intrinsic sugar lactose plus added sugars. UK labelling laws do not require the declaration of added sugars on nutrition labels and the UK's sugar reduction guidelines focus on total sugars for this reason. Interestingly, although food companies have argued it is difficult to measure, the inclusion of added sugars (under total sugars) on food labels has been recently mandated in the US; companies have until 2020 or 2021 to implement depending on their size.[44] It will be interesting to see how food product companies and consumers navigate these changes. Our study highlighted other potential challenges and mixed messages for consumers, arising from marketing and packaging. Many products that were suggested for children's lunchboxes on supermarket websites were very high sugar desserts (from jelly to dairy based) rather than yogurt or fromage frais. Retailers could play a positive role in promoting health here by establishing boundaries for inclusion in lunchbox recommendations. Furthermore, the portion sizes for children's yogurts varied enormously and were often identical to adult portion sizes. Equally there was little consistency in portion size in adult yogurts either, and particularly for larger pots (400-500g) of yogurt the serving size was either not given or was different from the equivalent smaller pot of yogurts (100-150g/serving). In multiple products with added plant stanols marketed for their cholesterol lowering merits, none would meet a low sugar claim and several were extremely high in sugar. In light of data linking high sugar consumption to high cholesterol levels,[45] arguably these products should be scrutinised for reformulation.

The UK guidelines for sugar reduction in the yogurt and fromage frais category, do not apply to dairy desserts, natural/unsweetened yogurt/fromage frais, and yogurt/dairy drinks (although 'any sugar-sweetened yogurt and dairy drinks that are excluded from the soft drinks industry levy will become part of the sugar reduction programme').[37] But it was interesting to note the median of sugar content in plain, natural/Greek yogurts (5.0 g/100g), which is predominantly lactose, was higher than the allowance of 3.8g/100g that the UK guidelines agreed on for lactose. It should be noted that the guidelines have been made, in consultation with industry, on sales weighted averages so are not directly comparable here. This is calculated by weighting the sugar level of individual products by their volume sales, so that high selling products with high sugar levels will push sales weighted average upwards. For yogurt, the reported baseline sales weighted average was 12.8g/100g, with a 20% reduction aim for 11.0g/100g product; the report suggests reformulation, reducing portion size and shifting portfolio of sales are all viable mechanisms to help achieve this.[37] While median sugar values are not directly comparable to sales weighted averages, our study suggests the organic (13.1g/100g), fruit (11.9g/100g) and flavoured (12.0g/100g) categories require the greatest changes. Children's yogurt and fromage frais products had a somewhat lower median of sugar 10.8g/100g, possibly meeting government guidelines (not clear as not sales weighted). However, given the recommendations that 4-6 year olds should have no more than 19g of sugar a day, a single pot of yogurt can contribute substantially to sugar intakes of children. The sugar content of children's yogurts and fromage frais varied dramatically and there was no difference between the sugar contents of yogurts and fromage frais per 100g of product. However, as fromage frais has a much smaller serving size (median 47g vs 90g for yogurt), fromage frais products contained much less sugar than yogurt per serving (5.4 vs 9.2 g sugar/serving); with a single serving of yogurt on average delivering close to half of a child's daily maximal recommended intake of sugar.

Reformulation is likely to be challenging; beyond acting as a sweetener, added sugar in foods acts as a bulking and colouring agent, and the use of sugar in foods is dictated by physical and chemical properties that are difficult to substitute.[46] In addition, in general consumers 'liking' for yogurt is correlated positively with sweetness.[47] Lactic fermentation yields a sour taste that sugar attenuates. Consumers have been shown to prefer yogurt containing 10-13% added sugar but may accept products with 7% added sugar while rejecting products with 5% or less added sugars as too sour, or adding sweeteners (caster sugar, jam or honey) themselves before consuming.[47-50] When Saint-Eve and colleagues[50] precisely measured sugar added by 204 French subjects to natural yogurt they found on average participants added 13.6 g of sugar to their yogurts, more than total content of many commercial sweetened yogurts. Participants underestimated how much sugar they were adding but still perceived their addition of sweetener to be the healthier option.[50]

Although we have focussed our attention on the sugar content of yogurts per se, it is important to consider other nutrients, not least because of the impact on the glycaemic response. Notably, our work

illustrates that natural/Greek yogurts have a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% energy vs range of 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) than all other categories. The observed glycaemic index (GI) of yogurts are generally much lower than predicted values calculated from their carbohydrate contents, with unsweetened yogurts having the lowest GI of all; this is contributed both to the fact that lactose has a low GI, but also because yogurts' protein content will reduce the glycemic response.[51]

We had preconceived that low-fat yogurts would contain more sugar than their high-fat alternatives, in part because of a previous, short report from an American database analysis that showed low-fat products, including yogurts, contain more sugar than their higher fat counterparts.[39] In contrast, low-fat products surveyed here had significantly lower sugar in low-fat products (10.3 vs 13.1g/100g in high-fat). However, we note that although low-fat products did have less sugar on average, nonetheless approximately 50% of low-fat products had between 10-20g sugar/100g. With an energy intake of 2000 kcal/day, 5% of added sugars is 25g, and a single serving of yogurt in all categories surveyed, other than natural/Greek, can easily provide half or more of this. On the other hand, a 150g serving of the median sugar (16.4g/100g) dessert product could provide a person their 25g daily limit of sugars. Nonetheless, low-fat products had lower energy, fat and sugar contents, and were slightly higher in protein, in comparison to high-fat products. This profile appears consistent with current UK and US dietary guidelines that recommend low-fat dairy products out of concerns for obesity and cardiovascular disease. However, evidence is accumulating that high-fat rather than low-fat dairy is associated with a lower risk of obesity and diabetes,[21 23-25] including several studies that suggest full fat milk is associated with reduced risk of overweight and obesity in children. [25 52 53]

The study has some limitations. We would have liked to have included products sold outside the five major online supermarkets but this would have created difficulties in data collections and setting the boundary of inclusion. However, the supermarkets included covered 75 % of the grocery market and is therefore representative of the overall market, and as such provides a useful database for discussion. Ideally data collection should take place in as narrow a timeframe as possible and we took only a month here. However, manufacturers may have made changes to products since this snapshot and it would be interesting to repeat the survey in future years. As nutrient data was collected from online information, provided by supermarkets or the brand's own website; these data may not always be up to date or accurate. We did not incorporate analysis of price here; it would be interesting to assess if sugar or other nutrients relate to price.

Conclusions

While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in nutrient content. In a comprehensive survey of the UK supermarket yogurt products we highlight here that the median sugar content of children's, fruit, flavoured, and organic yogurt categories

were well above 10g/100g and represented >45% of total energy derived. Organic yogurts (including organic yogurt with added fruit or flavourings etc) had the highest median sugar content (13.1g/100g). Notably, natural/Greek yogurts had a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% vs range of 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) contents than all other categories. While natural/Greek yogurts contained the least amount of sugars, their median total sugar (5.0g/100g, largely lactose) was markedly higher than the agreed allowance (3.8g/100g) for lactose. Low-fat products had less sugar and energy than high-fat yogurts. Within the children's category, fromage frais had higher protein and calcium contents/100g than yogurts and was marketed with smaller serving sizes. Less than 3% of children's products were low in sugar, and many products recommended for lunchboxes were high sugar desserts. We conclude, not all yogurts are as healthy as perhaps consumers perceive them, as the majority are high in sugars and reformulation for the reduction of added sugars is warranted.

Contributors

JBM designed the study, analysed the data and wrote the manuscript. AH carried out the study, analysed the data and contributed to a preliminary draft. BF helped design and interpret the study and revised the manuscript critically for important intellectual content.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests

None

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Tables

Table 1. Definitions[1].

Term	Definition
Sugars[2]	Conventionally describes chemically the monosaccharides (glucose, fructose, galactose) and disaccharides (sucrose, lactose[3], maltose).
Total Sugars	Currently required for UK nutrition label. Includes sugars occurring naturally in foods and beverages and those added during processing and preparation.
Free Sugars	"All monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices. Under this definition lactose[3] when naturally present in milk and milk products is excluded."[36]
Added Sugars	Equivalent to 'free sugars'; "Syrups and other caloric sweeteners used as a sweetener in other food products. Naturally occurring sugars such as those in fruit or milk are not added sugars."[54] Will be a required subline under 'total sugars' for US food labels from 2020.[44]

[1]Adapted with permission from Moore and Fielding.[34]
[2]Examples of sugars commonly found as ingredients: Sucrose, fructose, glucose, dextrose, maltose, lactose, trehalose, brown sugar, turbinado sugar, demerara sugar, raw sugar, cane sugar, fruit sugar, invert sugar, corn sweetener, corn syrup, high-fructose corn syrup, malt syrup, glucose syrup, glucose-fructose syrup, fructose-glucose syrup, honey, molasses, date syrup, agave syrup.
[3]Lactose is often called 'milk sugar', because 100% of 'total sugars' in milk are lactose. In natural/Greek yogurt ~80% of the sugar is lactose, with the remainder being galactose generated from lactose fermentation.[55]

Table 2. Macronutrients (% energy) across yogurt categories.

		Fat		Carbohydrates (*total sugars*)		Protein	
	N	Median	Range	Median	Range	Median	Range
Children's	101	26.2[a]	19.9, 40.8	52.0[a] *(45.5)*	25.4, 57.9	20.0[a]	13.1, 40.5
Dairy Alt.	38	30.2[a]	21.9, 86.3	50.8[a,b] *(48.4)*	7.1, 63.5	18.8[a]	2.4, 40.0
Dessert	161	32.6[a]	0.0, 63.1	55.0[c] (46.3)	29.0, 100	10.8[b]	0.0, 34.9
Drinks	70	17.1[b]	0.0, 54.8	62.4[c] (52.5)	25.6, 95.2	15.8[a]	7.9, 40.0
Flavoured	79	31.7[a]	0.0, 53.5	52.2[a,b] (45.8)	26.4, 69.6	14.7[a]	0.0, 70.0
Fruit	311	16.8[b]	0.0, 53.5	56.7[c] (52.8)	32.5, 78.1	18.1[a]	7.6, 61.5
Natural/Greek	61	25.9[a]	0.0, 75	34.7[b] (30.4)	32.5, 61.3	32.3[c]	11.4, 72.3
Organic	71	33.4[a]	0.0, 69.8	48.5[a,b] (46.7)	32.5, 73.5	17.5[a]	0.3, 56.3

[a,b,c]Median values within a column with unlike superscript letters were significantly different (P<0.0001) by Kruskal-Walis and Dunn's multiple comparison tests.

Table 3. Sugar and fibre in Fruit, Flavoured and Natural/Greek yogurt products.

	Fruit			Flavoured			Natural/Greek		
	N	Median	Range	N	Median	Range	N	Median	Range
Sugar (g/100g)	305	11.9[a]	4.6, 21.3	79	12.0[a]	0.1,18.8	60	5[b]	1.6, 9.5
Fibre (g/100g)	170	0.3[a]	0.0, 2.4	42	0[b]	0.0, 0.9	26	0[b]	0.0, 0.9

[a,b]Median values within a row with unlike superscript letters were significantly different (P<0.0001) by Kruskal-Walis and Dunn's multiple comparison

Figure Legends

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

Figure 2. Nutrient and energy contents of UK yogurt products across categories. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations[2] for nutrition claims for low sugar **A** and low fat **B**.

Figure 3. Nutrients compared across the high (n=383) and low (n=530) fat categories. **A** Sugar. **B** Fat. **C** Protein. **D** Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

References

1. Thorning TK, Bertram HC, Bonjour JP, et al. Whole dairy matrix or single nutrients in assessment of health effects: current evidence and knowledge gaps. *Am J Clin Nutr* 2017;105:1033-45. doi: 10.3945/ajcn.116.151548
2. European Parliament Council of the European Union. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union* 2006:L 404/9.
3. Morelli L. Yogurt, living cultures, and gut health. *Am J Clin Nutr* 2014;99:1248s-50s. doi: 10.3945/ajcn.113.073072
4. Ashraf R, Shah NP. Immune system stimulation by probiotic microorganisms. *Crit Rev Food Sci Nutr* 2014;54:938-56. doi: 10.1080/10408398.2011.619671
5. European Food Safety Authority. Scientific Opinion on the substantiation of health claims related to live yoghurt cultures and improved lactose digestion. 2010;8:1763.
6. Marette A, Picard-Deland E. Yogurt consumption and impact on health: focus on children and cardiometabolic risk. *Am J Clin Nutr* 2014;99:1243s-7s. doi: 10.3945/ajcn.113.073379
7. Cormier H, Thifault E, Garneau V, et al. Association between yogurt consumption, dietary patterns, and cardio-metabolic risk factors. *Eur J Nutr* 2016;55:577-87. doi: 10.1007/s00394-015-0878-1
8. Zhu Y, Wang H, Hollis JH, et al. The associations between yogurt consumption, diet quality, and metabolic profiles in children in the USA. *Eur J Nutr* 2015;54:543-50. doi: 10.1007/s00394-014-0735-7
9. Wang H, Livingston KA, Fox CS, et al. Yogurt consumption is associated with better diet quality and metabolic profile in American men and women. *Nutr Res* 2013;33:18-26. doi: 10.1016/j.nutres.2012.11.009
10. Aune D, Norat T, Romundstad P, et al. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. *Am J Clin Nutr* 2013;98:1066-83. doi: 10.3945/ajcn.113.059030
11. Gao D, Ning N, Wang C, et al. Dairy products consumption and risk of type 2 diabetes: systematic review and dose-response meta-analysis. *PLoS One* 2013;8:e73965. doi: 10.1371/journal.pone.0073965
12. Chen M, Sun Q, Giovannucci E, et al. Dairy consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *BMC Med* 2014;12:215. doi: 10.1186/s12916-014-0215-1
13. Gijsbers L, Ding EL, Malik VS, et al. Consumption of dairy foods and diabetes incidence: a dose-response meta-analysis of observational studies. *Am J Clin Nutr* 2016;103:1111-24. doi: 10.3945/ajcn.115.123216
14. Tremblay A, Panahi S. Yogurt Consumption as a Signature of a Healthy Diet and Lifestyle. *The J Nutr* 2017;147:1476s-80s. doi: 10.3945/jn.116.245522
15. Wu L, Sun D. Consumption of Yogurt and the Incident Risk of Cardiovascular Disease: A Meta-Analysis of Nine Cohort Studies. *Nutrients* 2017;9 doi: 10.3390/nu9030315
16. Guo J, Astrup A, Lovegrove JA, et al. Milk and dairy consumption and risk of cardiovascular diseases and all-cause mortality: dose-response meta-analysis of prospective cohort studies. *EurJ Epidemiol* 2017;32:269-87. doi: 10.1007/s10654-017-0243-1
17. Sayon-Orea C, Martinez-Gonzalez MA, Ruiz-Canela M, et al. Associations between Yogurt Consumption and Weight Gain and Risk of Obesity and Metabolic Syndrome: A Systematic Review. *Adv Nutr* 2017;8:146s-54s. doi: 10.3945/an.115.011536
18. Schwingshackl L, Hoffmann G, Schwedhelm C, et al. Consumption of Dairy Products in Relation to Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Cohort Studies. *PLoS One* 2016;11:e0157461. doi: 10.1371/journal.pone.0157461
19. Santiago S, Sayon-Orea C, Babio N, et al. Yogurt consumption and abdominal obesity reversion in the PREDIMED study. *Nutr Metab Cardiovasc Dis* 2016;26:468-75. doi: 10.1016/j.numecd.2015.11.012

20. Guasch-Ferre M, Becerra-Tomas N, Ruiz-Canela M, et al. Total and subtypes of dietary fat intake and risk of type 2 diabetes mellitus in the Prevencion con Dieta Mediterranea (PREDIMED) study. *Am J Clin Nutr* 2017;105:723-35. doi: 10.3945/ajcn.116.142034
21. Kratz M, Baars T, Guyenet S. The relationship between high-fat dairy consumption and obesity, cardiovascular, and metabolic disease. *Eur J Nutr* 2013;52:1-24. doi: 10.1007/s00394-012-0418-1
22. Weaver CM. How sound is the science behind the dietary recommendations for dairy? *Am J Clin Nutr* 2014;99:1217s-22s. doi: 10.3945/ajcn.113.073007
23. Holmberg S, Thelin A. High dairy fat intake related to less central obesity: a male cohort study with 12 years' follow-up. *Scand J Prim Health Care* 2013;31:89-94. doi: 10.3109/02813432.2012.757070
24. Rautiainen S, Wang L, Lee IM, et al. Dairy consumption in association with weight change and risk of becoming overweight or obese in middle-aged and older women: a prospective cohort study. *Am J Clin Nutr* 2016;103:979-88. doi: 10.3945/ajcn.115.118406
25. Beck AL, Heyman M, Chao C, et al. Full fat milk consumption protects against severe childhood obesity in Latinos. *Prev Med Rep* 2017;8:1-5. doi: 10.1016/j.pmedr.2017.07.005
26. Chowdhury R, Warnakula S, Kunutsor S, et al. Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis. *Ann Intern Med* 2014;160:398-406. doi: 10.7326/m13-1788
27. Williams EB, Hooper B, Spiro A, et al. The contribution of yogurt to nutrient intakes across the life course. *Nutr Bull* 2015;40:9-32. doi: 10.1111/nbu.12130
28. Rizzoli R. Dairy products, yogurts, and bone health. *Am J Clin Nutr* 2014;99:1256s-62s. doi: 10.3945/ajcn.113.073056
29. Salas MM, Nascimento GG, Vargas-Ferreira F, et al. Diet influenced tooth erosion prevalence in children and adolescents: Results of a meta-analysis and meta-regression. *J Dent* 2015;43:865-75. doi: 10.1016/j.jdent.2015.05.012
30. Lythgoe A, Roberts C, Madden AM, et al. Marketing foods to children: a comparison of nutrient content between children's and non-children's products. *Public Health Nutr* 2013;16:2221-30. doi: 10.1017/s1368980013000943
31. Walker RW, Goran MI. Laboratory Determined Sugar Content and Composition of Commercial Infant Formulas, Baby Foods and Common Grocery Items Targeted to Children. *Nutrients* 2015;7:5850-67. doi: 10.3390/nu7075254
32. Azais-Braesco V, Sluik D, Maillot M, et al. A review of total & added sugar intakes and dietary sources in Europe. *Nutr J* 2017;16:6. doi: 10.1186/s12937-016-0225-2
33. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. *J Dent Res* 2014;93:8-18. doi: 10.1177/0022034513508954
34. Moore JB, Fielding BA. Sugar and metabolic health: is there still a debate? *Curr Opin Clin Nutr Metab Care* 2016;19:303-09. doi: 10.1097/MCO.0000000000000289
35. National Statistics. Statistics on Obesity, Physical Activity and Diet, England 2017. 2017
36. Scientific Advisory Committee on Nutrition. Carbohydrates and Health. London: The Stationery Office, 2015.
37. Public Health England. Sugar reduction: Achieving the 20%, 2017.
38. Kantar Worldpanel. Grocery market Share for Great Britain 2017 [Available from: https://www.kantarworldpanel.com/en/grocery-market-share/great-britain accessed November 24th, 2017
39. Nguyen PK, Lin S, Heidenreich P. A systematic comparison of sugar content in low-fat vs regular versions of food. *Nutr Diabetes* 2016;6:e193. doi: 10.1038/nutd.2015.43
40. Public Health England. National Dental Epidemiology Programme for England: Oral health survey of five-year-old children 2012 A report on the prevalence and severity of dental decay. 2012
41. Royal College of Surgeons: Faculty of Dental Surgery. The state of children's oral health in England. 2015
42. Health and Social Care Information Centre. Statistics on Obesity, Physical Activity and Diet: England 2017 2017 [Available from: https://www.gov.uk/government/statistics/statistics-on-obesity-physical-activity-and-diet-england-2017.

43. Lee W-cJ, Shimizu M, Kniffin KM, et al. You taste what you see: Do organic labels bias taste perceptions? *Food Qual Pref* 2013;29:33-39. doi: https://doi.org/10.1016/j.foodqual.2013.01.010
44. Food and Drug Administration. Food Labeling: Revision of the Nutrition and Supplement Facts Labels. *Federal Register* 81:Docket No. FDA–2012–N–1210.
45. Te Morenga LA, Howatson AJ, Jones RM, et al. Dietary sugars and cardiometabolic risk: systematic review and meta-analyses of randomized controlled trials of the effects on blood pressure and lipids. *Am J Clin Nutr* 2014;100:65-79. doi: 10.3945/ajcn.113.081521
46. Chinachoti P. Carbohydrates: functionality in foods. *Am J Clin Nutr* 1995;61:922s-29s.
47. Bayarri S, Carbonell I, Barrios EX, et al. Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *Int Dairy J* 2011;21:111-18. doi: https://doi.org/10.1016/j.idairyj.2010.09.002
48. Johansen SB, Næs T, Øyaas J, et al. Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Qual Pref* 2010;21:13-21. doi: https://doi.org/10.1016/j.foodqual.2009.07.003
49. Chollet M, Gille D, Schmid A, et al. Acceptance of sugar reduction in flavored yogurt. *J Dairy Sci* 2013;96:5501-11. doi: 10.3168/jds.2013-6610
50. Saint-Eve A, Leclercq H, Berthelo S, et al. How much sugar do consumers add to plain yogurts? Insights from a study examining French consumer behavior and self-reported habits. *Appetite* 2016;99:277-84. doi: 10.1016/j.appet.2016.01.032
51. Wolever TM. Yogurt Is a Low-Glycemic Index Food. *J Nutr* 2017;147:1462s-67s. doi: 10.3945/jn.116.240770
52. Scharf RJ, Demmer RT, DeBoer MD. Longitudinal evaluation of milk type consumed and weight status in preschoolers. *Arch Dis Child* 2013;98:335-40. doi: 10.1136/archdischild-2012-302941
53. Bigornia SJ, LaValley MP, Moore LL, et al. Dairy intakes at age 10 years do not adversely affect risk of excess adiposity at 13 years. *J Nutr* 2014;144:1081-90. doi: 10.3945/jn.113.183640
54. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition ed, 2015.
55. Public Health England. McCance and Widdowson's The Composition of Foods Integrated Dataset, 2015.

Figure 1

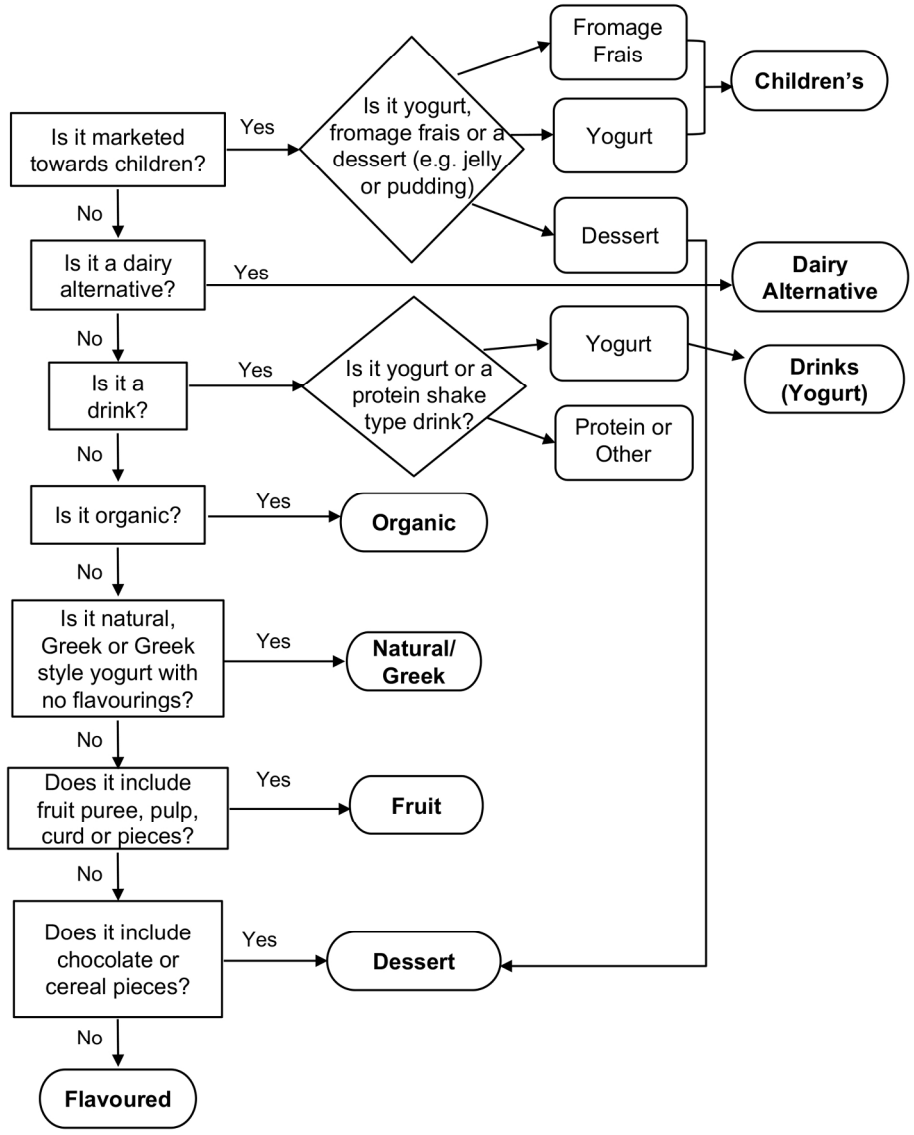

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

163x207mm (300 x 300 DPI)

Figure 2

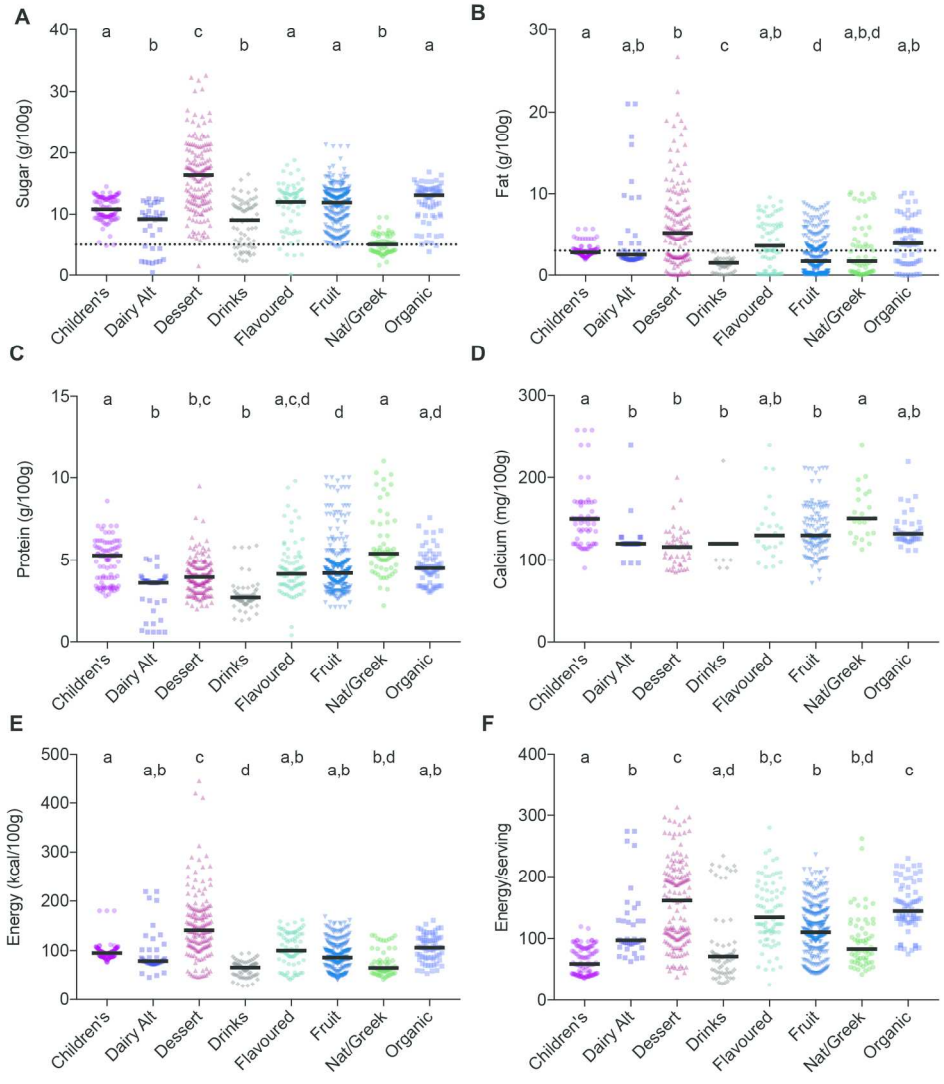

Figure 2. Nutrient and energy contents of UK yogurt products across categories. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations2 for nutrition claims for low sugar A and low fat B.

184x215mm (300 x 300 DPI)

Figure 3

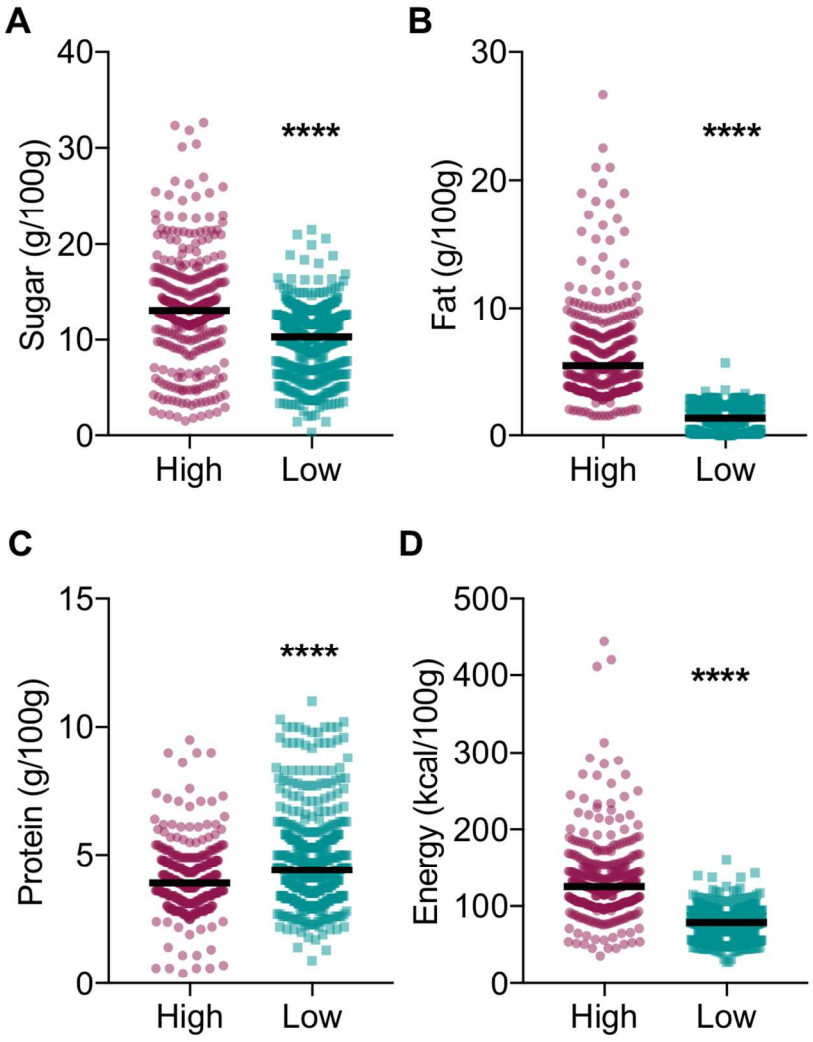

Figure 3. Nutrients compared across the high (n=383) and low (n=530) fat categories. A Sugar. B Fat. C Protein. D Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

99x132mm (300 x 300 DPI)

Figure 4

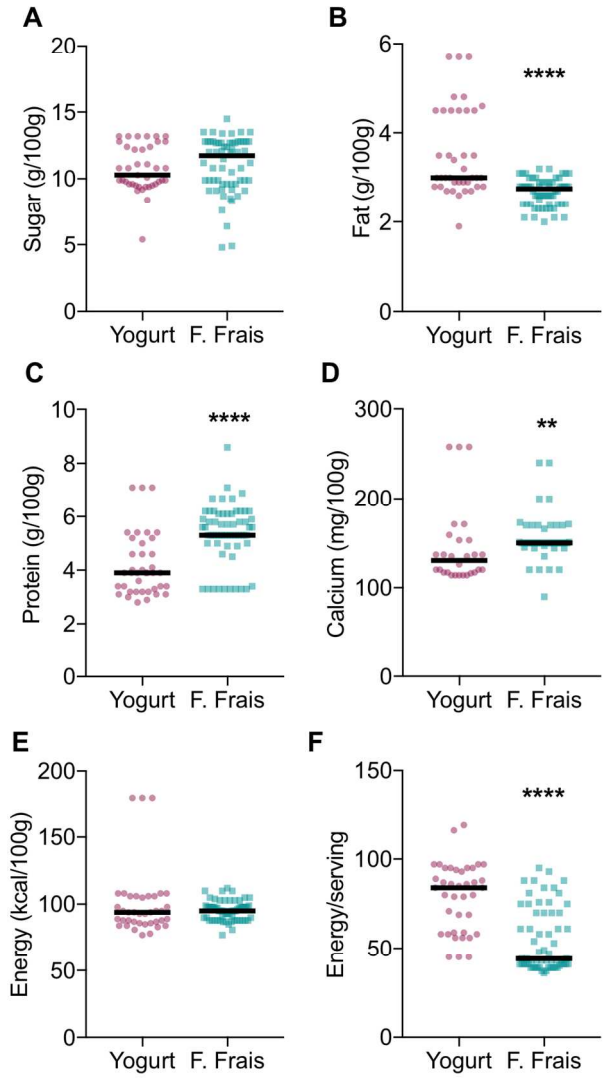

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

97x175mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **Done p1, p2**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Done p2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Done p4 and p5**
Objectives	3	State specific objectives, including any prespecified hypotheses **Done p6**
Methods		
Study design	4	Present key elements of study design early in the paper **Done p7**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Done p7 (recruitment N/A)**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **Not applicable**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Figure 4.** Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Done p7**
Bias	9	Describe any efforts to address potential sources of bias **Done p12_L311-319**
Study size	10	Explain how the study size was arrived at **Done p7 and p12_L311-315**

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Done p7**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses **Done p7**

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram **Not applicable**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) **Not applicable**
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures **Not applicable**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Not applicable**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **Done p7**
Discussion		
Key results	18	Summarise key results with reference to study objectives **Done p10**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Done p12**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Done p12-13 L313-314**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Done p12_L321-335**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Done p14**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

An evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-021387.R2
Article Type:	Research
Date Submitted by the Author:	28-May-2018
Complete List of Authors:	Moore, Bernadette; University of Leeds , School of Food Science and Nutrition; University of Surrey Horti, Annabelle; University of Leeds , School of Food Science and Nutrition Fielding, Barbara; University of Surrey, Department of Nutritional Sciences
Primary Subject Heading:	Nutrition and metabolism
Secondary Subject Heading:	Dentistry and oral medicine, Diabetes and endocrinology, General practice / Family practice, Health policy, Paediatrics
Keywords:	Yogurt, Sugar, Children, Obesity

TITLE PAGE

Title

An evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets

Author names

J. Bernadette Moore[1,2], Annabelle Horti[1] and Barbara A. Fielding[2]

Author affiliations

[1]School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK

[2]Department of Nutritional Sciences, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, UK

Corresponding author

Dr. J. Bernadette Moore

University of Leeds

School of Food Science and Nutrition

Leeds

LS2 9JT, UK

Tel: +44 (0) 113 343 9900

Email: j.b.moore@leeds.ac.uk

Running title

Nutrient content of yogurts in the UK

Keywords

Yogurt, Sugar, Children, Obesity

Abstract

Objectives: To comprehensively survey the sugar and nutrient contents of yogurt products available in UK supermarkets, in particular those marketed to children.

Design: A cross sectional survey of yogurt products available in the UK's supermarkets in November 2016.

Methods: Data were collected from five major online UK supermarkets and a process flow strategy was used to place yogurts into eight categories: children's, dairy alternatives, dessert, drinks, fruit, flavoured, natural/Greek style and organic. A comprehensive database of product information for 921 unique products was created and analysed.

Results: The total sugar, fat, protein, calcium and energy contents were highly variable across categories, and the ranges were extremely broad. Although lower than the dessert category, the median[range] of the total sugar content of children's (10.8g/100g [4.8, 14.5]), fruit (11.9g/100g [4.6, 21.3]), flavoured (12.0g/100g [0.1, 18.8]), and organic (13.1g/100g [3.8, 16.9]), yogurt products were all well above 10g/100g, and represented >45% of total energy. Only 2 out of 101 children's yogurt and fromage frais products surveyed qualified as low-sugar (≤5g/100g). Natural/Greek yogurts had dramatically lower sugar contents (5.0g/100g [1.6, 9.5], largely lactose) than all other categories. While low-fat (<3g/100g) products had less sugar and energy than higher-fat yogurts, nonetheless 55% (285 of 518 low-fat yogurts) contained between 10-20g sugar/100g. Within the children's category, fromage frais had higher protein (5.3g/100g [3.3, 8.6] vs. 3.2 [2.8, 7.1]; P <0.0001) and calcium contents (150mg/100g [90, 240] vs. 130.5 mg/100g [114, 258]; P= 0.0015) than yogurts.

Conclusions: While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in total sugars. Fewer than 9%, and only 2% of the children's, products surveyed were low enough in sugar to earn 'green' in UK front of the pack labelling. Reformulation for the reduction of free sugars in yogurts is warranted.

Strengths and limitations of this study

- This was a comprehensive market survey that analysed the nutrient contents of 921 supermarket products identified by the search term yogurt/yoghurt in five major UK supermarkets, representing 75% of UK grocery market share, online in November 2016.
- A systematic process flow strategy was determined *a priori* and utilised for categorising products.
- The energy and nutrient contents of products within categories are individually presented readily permitting differences and ranges between categories to be seen.
- Products were identified by supermarket categorisation and some products included in this market survey for completeness did not contain yogurt cultures (e.g. fromage frais, desserts), which may have skewed results.
- The nutrient information utilised here came from the manufacturers and supermarkets online and may not have been accurate or up-to-date; and the survey did not include less well-known yogurt brands, produced or sold by small-scale local food manufacturers, or yogurts sold in dessert shops.

Introduction

The association between dairy foods and disease risk has often been contradictory, likely due to inherent diversity in the nutrient contents and food matrices of different dairy products.[1] Yogurt is the product of milk fermented with the lactic cultures *Streptococcus thermophiles* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, which can be enhanced with other probiotic cultures such as *Lactobacillus acidophilus* and *Bifidobacterium bifidus*.[2] Consumption of fermented dairy products has long been considered to be beneficial to digestive and overall health.[3] The beneficial probiotic and immune regulatory effects of yogurts underpin their recommendation as a healthy food for babies and children.[4] Multiple regulatory bodies, including the European Food Safety Authority, have approved health claims related to yogurt consumption and reduction in symptoms caused by lactose maldigestion.[5] In addition to probiotics, yogurt is a good source of protein, calcium, iodine and vitamin $B_{12,}$ and its consumption has been associated with lower risk of obesity and cardiometabolic risk in both children and adults.[6 7]

Evidence is accumulating that frequent yogurt consumption may be associated with healthier metabolic profiles in both children and adults.[8 9] In adults, increased yogurt consumption has been associated with lower levels of circulating triglycerides, glucose and lower systolic blood pressure;[9] and several recent meta-analyses have demonstrated that increased yogurt consumption is inversely associated with the risk of developing type 2 diabetes.[10-13] Notably, across three large American cohort studies (the Health Professionals Follow-Up Study and the Nurses' Health Studies I and II) in >190,000 adults and >30 years follow-up; while there was no effect of dairy on incident type 2 diabetes (T2D), yogurt intake specifically was inversely associated with T2D risk across the three cohorts with a pooled hazard ratio of 0.83 (0.75, 0.92) for one serving/day.[12] Although confounders were statistically accounted for, an acknowledged limitation to these epidemiology studies is the evidence that yogurt is a general marker of healthy dietary habits.[9 14] Data are more equivocal regarding yogurt consumption and cardiovascular disease risk, although one study suggested a possible lowered risk at higher levels of yogurt intakes (>200g/d),[15] a more recent and comprehensive meta-analysis showed no benefit.[16] High quality and adequately powered randomised controlled trials are lacking however.

Prospective cohort studies have, in general, shown inverse associations between yogurt intakes and changes in waist circumference, weight and risk of overweight or obesity; with some inconsistencies between studies.[17,18] More recently, in an elderly Italian population cohort of >4,000 at high cardiovascular risk, consumption of whole-fat yogurt (but not total yogurt) was associated with changes in waist circumference and higher probability for reversion of abdominal obesity and lower risk of diabetes.[19,20] This is in line with a previous systematic review of observational studies on the relationship between dairy fat, obesity, and cardiometabolic disease; in 11 of 16 studies included in the review, high-fat dairy intake was inversely associated with measures of adiposity.[21] While dietary guidelines vary by

region, most countries make dietary recommendations for the consumption of dairy products because of the strong evidence for the role of dairy products in meeting nutrient intake requirements.[22] In both the US and UK, current dietary guidelines recommend low-fat and low-sugar dairy products because of obesity related concerns; however, a growing number of recent studies suggest that high-fat dairy consumption is associated with a lower risk of obesity and diabetes[21 23-25] Large cohort studies in Sweden (n=1782 males 40-60 years old)[23] and the US (n=18, 438 women ≥45 years old in the Women's Health Study)[24] have found high-fat dairy to be protective against developing central adiposity and becoming overweight or obese at follow up. These data have fed into ongoing wider debate regarding dietary guidance related to fat, refined carbohydrates, and cardiovascular disease risk.[26]

In the UK, on average, children consume more yogurt than adults, and children under three years of age have the highest intakes.[27] Yogurt contributes a significant percentage of the daily RNI of key nutrients to babies and children up to 10 years of age, providing for example: 10-19% calcium, 11-20% phosphorus, 10-21% riboflavin and 17-54% vitamin B_{12}.[27] Yogurts are often recommended to be part of children's diets due to their high calcium content and its positive effect on bone development.[28] Calcium also has a positive effect on teeth and high intakes of milk and yogurt products in multiple studies have been associated with reduced tooth erosion.[29] However, although there is good evidence to suggest that yogurt can be beneficial to health, products on the market may vary widely in sugar content and yogurt marketed specifically to children may be higher in free or added sugars (see Table 1 for definitions of free, added and total sugars).[30 31] Dairy is a significant contributor to the intakes of free sugars by children and adults.[32] Diets high in free sugars are now unequivocally linked to obesity and dental caries, prompting the World Health Organisation and other regulatory bodies in updating dietary guidelines to strongly advocate for restricting free sugars intakes to less than 10% of total energy.[33 34] With an alarming 58% of women and 68% of men along with 1 in 3 of UK children aged 10-11 years overweight or obese in 2015,[35] the UK's guidelines more stringently recommended the restriction of free sugars to less than 5% of total daily energy.[36] As part of a plan to combat childhood obesity, in April 2018 the UK government implemented an industry soft drinks levy and commissioned a structured programme of monitored sugar reduction as part of wider reformulation tackling calories, salt and saturated fat.[37] The initial focus was on the top 9 food categories (after soft drinks and fruit juices and smoothies) that contribute the most to children's sugar intakes. These are: chocolate, confectionery, biscuits, breakfast cereals, cakes, morning goods (such as croissants, buns and waffles), ice cream, yogurt and sweet spreads/sauces. Yogurt was one of the products identified and highlighted for a 20% reduction of sugar by 2020, with guidelines given for energy per portion size of 120kcal sales weighted average; 175kcal maximum per portion and an allowance made for lactose (3.8g/100g).[37]

In this context then, the aims of this work were to perform a comprehensive survey of yogurt products within the major UK supermarkets, in order to identify products marketed at children and to evaluate their nutrient contents, in particular sugar, compared with other categories.

Experimental methods

Data collection

Data were collected from five major UK online supermarkets (Asda, Morrisons, Sainsbury's, Tesco and Waitrose) that account for 75% of the UK grocery market share.[38] Websites were searched from 07/10/16-16/11/16 using 'yogurt' or 'yoghurt' as a search term (in 4 of 5 supermarkets the same number of products were returned). After considering the product groupings commonly used by online supermarkets, eight categories (children's, dairy alternatives, dessert, drinks, flavoured, fruit, natural/Greek, organic) and a systematic process flow strategy for product placement (Fig. 1) was decided upon *a priori*. These product groupings, and those typically used by supermarkets for both inventory and marketing reasons, go beyond the standard broad sub-groupings used in dietary surveys such as the UK National Dietary and Nutrition Survey (NDNS), where the main food group '15: Yogurt, fromage frais and other dairy desserts' has only 3 broad subsidiary groups of either: 'yogurt'; 'manufactured fromage frais and other dairy desserts'; or 'homemade fromage frais and other dairy desserts'.[39] As dairy desserts for the NDNS includes 'chocolate and fruit cream desserts, mousse, milk jelly, junket, buttermilk desserts, fruit fools, creme caramel, panna cotta, chilled soya desserts, quark, egg custards'[39] we chose to include these products in the analyses here. Therefore, the dessert category contains both yogurt-based and other products (eg. jellies and puddings-i.e. chocolate mousse, crème caramels) that contain no yogurt or fromage frais cultures. However non-yogurt (e.g. high protein) drinks were removed from the nutrient analyses. Soya-based yogurts were placed in the 'dairy alternative' category, whereas Greek style yogurts with added honey or other sweeteners were placed in the 'flavoured' category. 'Fruit' was defined liberally, for example many products were made with either curd or purees and for lemon products in particular, often with juice. In the case of natural yogurts, if organic, they went in organic category. In scrutinising the children's category (products included were defined as 'children's' if either the supermarket or product itself defined it as such, or if spokes-characters, celebrities, cartoons, toy giveaways, games, or kids' clubs were incorporated into brand image), the ingredients lists were used to evaluate presence or absence of yogurt or fromage frais cultures.

For the classification of low-fat and low-sugar the cut-offs defined by EU regulations[2] currently used for voluntary, front-of-pack, traffic light coloured labels in the UK[40] were utilised. In this scheme green designates low, amber designates medium and red designates high levels of reference intakes. Low-fat is defined as ≤3g of fat/100g or ≤1.5g/100ml for drinks; low-sugar is defined by a maximum of 5 g total sugars/100g. For labelling, high fat and sugar (red) are defined at >17.5 g fat/100g and >22.5 g sugar/100g respectively. Notably for sugar, the current EU reference intakes are for 90g sugar in a 2000kcal diet; this represents 18% of total energy from sugars and is much higher than the recent UK and WHO targets of 5%-10% of energy from free sugars (25-50g sugar/day in a 2000kcal diet).[2,40]

Data were screened for duplicates and a non-redundant database of product information was created that included: nutrient information, serving size, size of pack, claims on pack and ingredients. Nutrient information was confirmed from the brand's own website where possible and a subset were examined during in-store visits. Information on macronutrients, including energy, fat, saturated fat, carbohydrates, sugar, fibre and protein were collected, as well as any information on micronutrients. Data for macronutrients have been expressed as g/100g product as well as % energy, as both are needed to evaluate its nutritional merits; e.g. a yogurt with a lower energy content per 100g may have a higher % energy from sugar than a product with a higher energy content. All data were independently double-checked and 5% of all entries were randomly selected and verified.

Data analysis

Pivot tables in Excel were used for building and manipulating the product database and statistical analyses were done utilising Graph Pad Prism 7.0c. Normality was examined using the D'Agostino-Pearson omnibus normality test and comparisons across all categories were made using the non-parametric Kruskal-Wallis test with Dunns multiple comparisons. For comparisons of two categories, again in not observing normal distributions, the non-parametric, two tailed Mann-Whitney tests were applied.

Patient and Public Involvement

Patients and the public were not involved in this research.

Results

Nine hundred and twenty-one products identified online during the period of the survey were initially included in the analysis. At the time of survey, although national branded products dominated the products available (n=648 national vs n=273 own brand products), only 65 products were available in all five supermarkets. Following the process flow strategy (Fig. 1) removed 23 non-yogurt, e.g. high protein type, beverages from the analyses and the remaining 898 products were classed as either: children's (n=101), dairy alternatives (n=38), dessert (n=161), drinks (n=70), flavoured (n=79), fruit (n=317), natural/Greek (n=61), organic (n=71).

In assessing nutrient contents across the surveyed products, the sugar content varied enormously both within and across our product categories (Fig. 2a). With the exception of the natural/Greek category, the median total sugar contents of all categories were well above the 5g/100g maximal threshold considered for a low-sugar nutrition label claim.[2 40] Products within the dessert category, unsurprisingly, had the highest median and broadest [range] of total sugar at 16.4g/100g [1.5, 32.6] (Fig. 2a). However, the children's, flavoured, fruit and organic categories all had relatively high, and similar, median total sugar contents ranging from 10.8g/100g (children's) to 13.1g/100g (organic). As the natural/Greek category by definition contained no added sweeteners, it had the lowest median amount of total sugars per product (5g/100g [1.6, 9.5]). These sugars will be ~80% lactose (Table 1), but notably the range observed here suggests many products will have higher than the allowance of 3.8g/100g specified for lactose in the UK sugar reduction programme guidelines. The dairy alternatives and drinks categories also had total sugar medians higher than 5g/100g, nonetheless these were still significantly lower that the children's, flavoured, fruit and organic categories with median[ranges] of 9.2g/100g [0.4, 12.5] for dairy alternatives and 9.1g/100g [2.3, 16.5] for drinks (Fig. 2a).

Somewhat in contrast to sugar, as seen in Fig. 2b, many yogurt categories (children's, dairy alternative, drinks, fruit, natural/Greek) had median levels of fat lower than the thresholds considered 'low-fat' for nutrition claims (3g/100g for food and 1.5g/100mL for drinks).[2] While flavoured and organic yogurts were just over this threshold with medians for fat of 3.6g/100g [0, 9.6] and 3.9g/100g [0, 10.1], respectively; the dessert category contained the highest median amount of fat and had the broadest range at 5.2g/100g [0, 26.7] (Fig. 2b). The drinks category had the lowest median fat contents at 1.5g/100g [0, 3.0], but the fruit and natural/Greek categories were also relatively low with medians of 1.6[0, 8.9] and 1.7[0, 10.1]g/100g respectively (Fig. 2b).

The natural/Greek and the children's categories had the highest median protein contents at 5.4[2.2, 11.0] and 5.3[2.8, 8.6] g/100g yogurt (Fig 2c). The higher protein median for the children's category was influenced, as expanded on below, to a significant degree by a large percentage of higher protein fromage frais products. The dessert, fruit, flavoured and organic categories had very similar median protein

contents 4.0-4.5 g/100g, whereas drinks and dairy alternatives contained the least amount of protein at 2.7 [1.3, 5.9] and 3.6[0.6, 5.2]g/100g (Fig 2c). Calcium values were less frequently reported, but median values between yogurt categories were broadly similar ranging from 116-150 mg/100g (Fig. 2d). Mimicking protein, the natural/Greek and the children's categories had the highest calcium contents. The dessert category, again not surprisingly, contained significantly more energy/100g (Fig. 2e) and more energy/serving (Fig. 2f) than any other category. Although the children's category had the least energy/serving (Fig. 2f), this was clearly because of smaller serving sizes. When expressed as kcal/100g, the median energy of children's yogurts was similar to products in the dairy alternative, flavoured, fruit and organic categories (ranging from 79-100g/100g), and these were significantly higher than the median (65g/100g) of the natural/Greek category (Fig. 2e).

In examining the macronutrient content (as % energy) of yogurts across categories, it was clear that the majority of carbohydrates in yogurt products are derived from sugars (Table 2). Carbohydrate content ranged from the extremes of 34.7% (natural/Greek) to 62.4% (drinks) of energy content, but all other categories were tightly bunched at 48.5-56.7% carbohydrate content. The natural/Greek category was significantly higher in protein (32.3%) than any other category, while the dessert category had the least amount of protein (10.8%) and highest percentage of fat (32.6%; Table 2). Although fruit and flavoured yogurts had very similar sugar contents (Table 2), fruit yogurts contained small, but appreciably more, amounts of fibre compared to flavoured or natural/Greek yogurts (0.3[0, 2.4] vs 0[0, 0.9] g/100g).

It has previously been reported from an analysis of a US database that low-fat products, including yogurts, contain more sugar than their higher-fat counterparts.[41] However, in comparing products below (n=518) and above (n=380) the ≤3 g/100g threshold for low-fat product labelling, we did not observe this here. Low-fat yogurt products had significantly lower amounts of sugar in comparison to higher-fat yogurts (10.7[0.1, 21.5] versus 13.1[0, 32.6] g/100g; Fig 3a) and much lower median and tighter range of fat contents (1.4[0, 3.0] versus 5.5[1.6, 26.7] g/100g; Fig 3b). Low-fat yogurts contained more protein than higher-fat products (4.3[0, 11.0] versus 3.9[0.1, 9.5] g/100g; Fig 3c) and much lower energy per 100g (81[28,143] versus 125[36, 445]g/100g; Fig 3d).

While fromage frais is also a fresh lactic fermented milk product, it is made with cheese cultures rather than yogurt cultures. In most of the categories, less than 5% of products were fromage frais and were not separated out. However, in the children's category, fromage frais dominated, representing 60% of products (n=62 vs n=39 yogurts) so their nutrient contents were assessed separately (Fig. 4). While there was no difference in the sugar content of children's yogurt and fromage frais (Fig. 4a); fromage frais products had lower fat (Fig. 4b; $P<0.0001$), higher protein (Fig. 4c; $P<0.0001$) and higher calcium (Fig. 4d; $P<0.01$) contents compared to children's yogurts. Although there was no difference in energy/100g (Fig. 4e), the energy/serving was significantly lower for fromage frais (Fig. 4f; $P<0.0001$) reflecting its often-smaller serving size.

Discussion

We have comprehensively evaluated yogurt products sold in the major UK supermarkets in November 2016, examining nutrient contents across categories, including those products marketed to children. Our results highlight that the total sugar content of yogurts is relatively high in all categories, with the exception of natural/Greek yogurts. Very few products, less than 9%, qualified for a low-sugar (≤5g/100g) claim for front of pack labelling, and almost none in the children's category. This is concerning given both the continued increase in childhood obesity and prevalence of tooth decay among children starting school (28%).[42] Tooth extractions are shockingly the primary reason children aged 5-9 are admitted to hospital with general anaesthetic in the UK.[43] Moreover, in 2015/16 more than 1 in 5 children in Reception (age 4-6), and 1 in 3 children in Year 6 (age 10-12) were measured as obese or overweight in England.[44] While yogurt may be less of a concern than soft drinks and fruit juices, the chief sources of free sugars in both children and adult's diets;[39] what is worrisome is that yogurt, as a perceived 'healthy food', may be an unrecognised source of free/added sugars in the diet. Indeed, a potentially surprising observation from our data was that, after the dessert category, it was organic yogurts that had the highest median sugar content (13.1g/100g). While the organic label refers to production, the well documented 'health halo' effect means that consumers most often underestimate the caloric content and perceive the nutritional contents of organic products, including yogurts, more favourably.[45]

An additional challenge for even an educated consumer is understanding that the total sugars on the label includes, in the case of yogurt, the intrinsic milk sugar, lactose, plus sugars added as sweeteners during processing. UK labelling laws do not require the declaration of free sugars on nutrition labels and the UK's sugar reduction guidelines focus on total sugars for this reason. Interestingly, although some have argued it is difficult to measure, the inclusion of added sugars (under total sugars) on food labels has been recently mandated in the US; companies have until 2020 or 2021 to implement depending on their size.[46] Notably, added sugars in the US do not include the sugars in juiced or pureed fruit and vegetables that are defined as free sugars by the UK and WHO. It has been argued for public health purposes, the emphasis in communication should be free sugars,[47] and it will be interesting to see how food product companies and consumers navigate these changes. Our study highlighted other potential challenges and mixed messages for consumers, arising from marketing and packaging. Many products that were suggested for children's lunchboxes on supermarket websites were very high sugar desserts (from jelly to dairy based) rather than yogurt or fromage frais. Retailers could play a positive role in promoting health here by establishing boundaries for inclusion in lunchbox recommendations. Furthermore, the portion sizes for children's yogurts varied enormously and were often identical to adult portion sizes. Equally there was little consistency in portion size in adult yogurts either, and particularly for larger pots (400-500g) of yogurt the serving size was either not given or was different from the equivalent smaller pot of

yogurts (100-150g/serving). In multiple products with added plant stanols marketed for their cholesterol lowering merits, none would meet a low-sugar claim and several were extremely high in sugar. In light of data linking high sugar consumption to high cholesterol levels,[48] arguably these products should be scrutinised for reformulation with a view to potential added health benefits in terms of obesity and dental caries.

The UK guidelines for sugar reduction in the yogurt and fromage frais category, do not apply to dairy desserts, natural/unsweetened yogurt/fromage frais, and yogurt/dairy drinks (although 'any sugar-sweetened yogurt and dairy drinks that are excluded from the soft drinks industry levy will become part of the sugar reduction programme').[37] But it was interesting to note the median of sugar content in plain, natural/Greek yogurts (5.0 g/100g), which is predominantly lactose, was higher than the allowance of 3.8g/100g that the UK guidelines agreed on for lactose. It should be noted that the guidelines have been made, in consultation with industry, on sales weighted averages so are not directly comparable here. This is calculated by weighting the sugar level of individual products by their volume sales, so that high selling products with high sugar levels will push sales weighted average upwards. For yogurt, the reported baseline sales weighted average was 12.8g/100g, with a 20% reduction aim for 11.0g/100g product; the report suggests reformulation, reducing portion size and shifting portfolio of sales are all viable mechanisms to help achieve this.[37] While median sugar values are not directly comparable to sales weighted averages, our study suggests the organic (13.1g/100g), fruit (11.9g/100g) and flavoured (12.0g/100g) categories require the greatest changes. Children's yogurt and fromage frais products had a somewhat lower median of sugar 10.8g/100g, possibly meeting government guidelines (not clear as not sales weighted). However, given the recommendations that 4-6 year olds should have no more than 19g of sugar a day, a single pot of yogurt can contribute substantially to sugar intakes of children. The sugar content of children's yogurts and fromage frais varied dramatically and there was no difference between the sugar contents of yogurts and fromage frais per 100g of product. However, as fromage frais has a much smaller serving size (median 47g vs 90g for yogurt), fromage frais products contained much less sugar per serving than yogurt (5.4 vs 9.2 g sugar/serving); with a single serving of yogurt on average delivering close to half of a child's daily maximal recommended intake of sugar.

Reformulation is likely to be challenging; beyond acting as a sweetener, added sugar in foods acts as a bulking and colouring agent, and the use of sugar in foods is dictated by physical and chemical properties that are difficult to substitute.[49] In addition, in general consumers 'liking' for yogurt is correlated positively with sweetness.[50] Lactic fermentation yields a sour taste that sugar attenuates. Consumers have been shown to prefer yogurt containing 10-13% added sugar but may accept products with 7% added sugar while rejecting products with 5% or less added sugars as too sour, or adding sweeteners (caster sugar, jam or honey) themselves before consuming.[50-53] When Saint-Eve and colleagues[53] precisely measured sugar added by 204 French subjects to natural yogurt they found on

average participants added 13.6 g of sugar to their yogurts, more than total content of many commercial sweetened yogurts. Participants underestimated how much sugar they were adding but still perceived their addition of sweetener to be the healthier option.[53]

Although we have focussed our attention on the sugar content of yogurts per se, it is important to consider other nutrients, not least because of the impact on the glycaemic response. Notably, our work illustrates that natural/Greek yogurts have a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% energy vs range of 10.8-20%) and much lower carbohydrate (34.7% vs 48.5-60.4%) than all other categories. The observed glycaemic index (GI) of yogurts are generally much lower than predicted values calculated from their carbohydrate contents, with unsweetened yogurts having the lowest GI of all; this is contributed both to the fact that lactose has a low GI, but also because yogurts' protein content will reduce the glycemic response.[54] Similarly, while some studies suggest lactose may be less cariogenic than other sugars,[55] it is recognised that the food components in unsweetened dairy products provide a buffering capacity that is protective to teeth enamel.[56] We might underscore therefore, that it is yogurts sweetened with added sugars that are primarily of concern here. In particular perhaps, for young children who derive a significant amount of their free sugar intake, which does not include lactose, from yogurt products (12% for 1.5-4 and 6% for 4-10 year olds),[39] at a time when taste preferences are being established for life.[57] Yogurt without added sugars remains a nutritious food for all ages and should ideally be introduced unsweetened during early childhood weaning. Although a drop in daily free sugars intake in the UK has been recently observed, currently consumption is well over 10% in all age groups, much higher than the 5% target. [39] While clearly in terms of dietary sugar intakes and obesity or dental caries, yogurt is not the concern sugar sweetened beverages are, which contribute to 25-40% of free sugar intake in 1.5-64 year olds,[39] nonetheless the rationale for reduction and reformulation across a broad range of products as part of a systemic approach to prevent obesity is robust.[34 58]

We had preconceived that low-fat yogurts would contain more sugar than their higher-fat alternatives, in part because of a previous, short report from an American database analysis that showed low-fat products, including yogurts, contain more sugar than their higher-fat counterparts.[41] In contrast, low-fat products surveyed here had significantly lower sugar than higher-fat products (10.3 vs 13.1g/100g in higher-fat). However, we note that although low-fat products did have less sugar on average, nonetheless 55% of low-fat products had between 10-20g sugar/100g. With an energy intake of 2000 kcal/day, 5% of energy amounts to 25g of sugar, and a single serving of yogurt in all categories surveyed, other than natural/Greek, can easily provide half or more of this. On the other hand, a 150g serving of the median sugar (16.4g/100g) dessert product could provide a person the recommended 25g daily limit of sugar. Nonetheless, low-fat products had lower energy, fat and sugar contents, and were slightly higher in protein, in comparison to higher-fat products. This profile appears consistent with current UK and US

dietary guidelines that recommend low-fat dairy products out of concerns for obesity and cardiovascular disease. Although it is notable that evidence is accumulating that higher-fat, rather than low-fat, dairy is associated with a lower risk of obesity and diabetes,[21 23-25] including several studies that suggest full fat milk is associated with reduced risk of overweight and obesity in children. [25 59 60]

The study has some limitations. We would have liked to have included products sold outside the five major online supermarkets but this would have created difficulties in data collections and setting the boundary of inclusion. However, the supermarkets included covered 75 % of the grocery market and is therefore representative of the overall market, and as such provides a useful database for discussion. Ideally data collection should take place in as narrow a timeframe as possible and we took only a month here. However, manufacturers may have made changes to products since this snapshot and it would be interesting to repeat the survey in future years. As nutrient data was collected from online information, provided by supermarkets or the brand's own website; these data may not always be up to date or accurate. We did not incorporate analysis of price here; it would be interesting to assess if sugar or other nutrients relate to price.

***Conclusion*s**

While there is good evidence that yogurt can be beneficial to health, products on the market vary widely in nutrient content. In a comprehensive survey of the UK supermarket yogurt products we highlight here that the median sugar content of children's, fruit, flavoured, and organic yogurt categories were well above 10g/100g and represented >45% of total energy derived. Organic yogurts (including organic yogurt with added fruit or flavourings etc) had the highest median sugar content (13.1g/100g). Notably, natural/Greek yogurts had a dramatically different macronutrient profile from all other categories, containing much higher protein (32.4% vs range of 10.8-20% energy) and much lower carbohydrate (34.7% vs 48.5-60.4% energy) contents than all other categories. While natural/Greek yogurts contained the least amount of sugars, their median total sugar (5.0g/100g, largely lactose) was markedly higher than the agreed allowance (3.8g/100g) for lactose. Although low-fat products had less sugar and energy than higher fat yogurts, nonetheless 55% of low-fat products contained 10-20 g sugar/100g. Within the children's category, fromage frais had higher protein and calcium contents/100g than yogurts and was marketed with smaller serving sizes. Less than 9%, and only 2% of children's, products surveyed were low enough in sugar to earn 'green' in UK front of the pack labelling; and many products recommended by supermarkets for lunchboxes were high sugar desserts. We conclude, not all yogurts are as healthy as perhaps consumers perceive them and reformulation for the reduction of free sugars is warranted.

Contributors

JBM designed the study, analysed the data and wrote the manuscript. AH carried out the study, analysed the data and contributed to a preliminary draft. BF helped design and interpret the study and revised the manuscript critically for important intellectual content.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing Interests

None

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Tables

Table 1. Definitions[1].

Term	Definition
Sugars[2]	Conventionally describes chemically the monosaccharides (glucose, fructose, galactose) and disaccharides (sucrose, lactose[3], maltose).
Total Sugars	Currently required for UK nutrition label. Includes sugars occurring naturally in foods and beverages and those added during processing and preparation.
Free Sugars	"All monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices. Under this definition lactose[3] when naturally present in milk and milk products is excluded."[36] Sugars present in intact fruit and vegetables are also excluded.
Added Sugars	"Syrups and other caloric sweeteners used as a sweetener in other food products. Naturally occurring sugars such as those in fruit or milk are not added sugars."[61] In addition, excludes sugars in juiced or pureed fruit and vegetables that are included in definition of free sugars. Will be a required subline under 'total sugars' for US food labels from 2020.[46]

[1]Adapted with permission from Moore and Fielding.[34]

[2]Examples of sugars commonly found as ingredients: Sucrose, fructose, glucose, dextrose, maltose, lactose, trehalose, brown sugar, turbinado sugar, demerara sugar, raw sugar, cane sugar, fruit sugar, invert sugar, corn sweetener, corn syrup, high-fructose corn syrup, malt syrup, glucose syrup, glucose-fructose syrup, fructose-glucose syrup, honey, molasses, date syrup, agave syrup.

[3]Lactose is often called 'milk sugar', because 100% of 'total sugars' in milk are lactose. In natural/Greek yogurt ~80% of the sugar is lactose, with the remainder being galactose generated from lactose fermentation.[62]

Table 2. Macronutrients across yogurt categories.

		Fat		Carbohydrates (*total sugars*)		Protein	
	N	Median	Range	Median	Range	Median	Range
				(% energy)			
Children's	101	26.2[a]	19.9, 40.8	52.0[a] *(45.5)*	25.4, 57.9	20.0[a]	13.1, 40.5
Dairy Alt.	38	30.2[a]	21.9, 86.3	50.8[a,b] *(48.4)*	7.1, 63.5	18.8[a]	2.4, 40.0
Dessert	161	32.6[a]	0.0, 63.1	55.0[c] (46.3)	29.0, 100	10.8[b]	0.0, 34.9
Drinks	70	17.1[b]	0.0, 54.8	62.4[c] (52.5)	25.6, 95.2	15.8[a]	7.9, 40.0
Flavoured	79	31.7[a]	0.0, 53.5	52.2[a,b] (45.8)	26.4, 69.6	14.7[a]	0.0, 70.0
Fruit	317	16.6[b]	0.0, 53.5	56.8[c] (52.8)	25.5, 78.1	17.7[a]	7.6, 61.5
Natural/Greek	61	25.9[a]	0.0, 75.0	34.7[b] (30.4)	11.3, 61.3	32.3[c]	11.4, 72.3
Organic	71	33.4[a]	0.0, 69.8	48.5[a,b] (46.7)	16.4, 73.5	17.5[a]	0.3, 56.3
				(g/100g)			
Children's	101	2.8[a]	1.9, 5.7	12.3[a] *(10.8)*	4.9, 25.0	5.3[a]	2.8, 8.6
Dairy Alt.	38	2.5[a,b]	1.9, 21.0	9.5[a] *(9.2)*	1.0, 16.2	3.6[b]	0.6, 5.2
Dessert	161	5.2[b]	0.0, 26.7	19.6[b] (16.4)	6.3, 54.9	4.0[b,c]	2.0, 9.5
Drinks	70	1.5[c]	0.0, 3.0	11.2[a] (9.1)	2.3, 18.4	2.7[b]	1.3, 5.9
Flavoured	79	3.6[a,b]	0.0, 9.6	13.0[a] (12.0)	3.7, 19.0	4.2[a,c,d]	0.4, 9.8
Fruit	317	1.6[d]	0.0, 8.9	12.9[a] (11.9)	4.8, 22.4	4.2[d]	2.1, 10.0
Natural/Greek	61	1.7[a,b,d]	0.0, 10.2	5.5[c] (5.0)	3.6, 9.5	5.4[a]	2.2, 11.0
Organic	71	3.9[a,b]	0.0, 10.1	13.3[a] (13.1)	4.8, 22.7	4.5[a,d]	3.0, 7.6

[a,b,c]Median values within a column with unlike superscript letters were significantly different (P<0.0001) by Kruskal-Walis and Dunn's multiple comparison tests.

Figure Legends

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

Figure 2. Nutrient and energy contents of UK yogurt products across categories. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations[2] for nutrition claims for low-sugar **A** and low fat **B**.

Figure 3. Macronutrients compared across low- (≤3g/100g; n=530) and higher- (>3g/100g; n=383) fat products. **A** Sugar. **B** Fat. **C** Protein. **D** Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

References

1. Thorning TK, Bertram HC, Bonjour JP, et al. Whole dairy matrix or single nutrients in assessment of health effects: current evidence and knowledge gaps. *Am J Clin Nutr* 2017;105:1033-45. doi: 10.3945/ajcn.116.151548
2. European Parliament Council of the European Union. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union* 2006:L 404/9.
3. Morelli L. Yogurt, living cultures, and gut health. *Am J Clin Nutr* 2014;99:1248s-50s. doi: 10.3945/ajcn.113.073072
4. Ashraf R, Shah NP. Immune system stimulation by probiotic microorganisms. *Crit Rev Food Sci Nutr* 2014;54:938-56. doi: 10.1080/10408398.2011.619671
5. European Food Safety Authority. Scientific Opinion on the substantiation of health claims related to live yoghurt cultures and improved lactose digestion. 2010;8:1763.
6. Marette A, Picard-Deland E. Yogurt consumption and impact on health: focus on children and cardiometabolic risk. *Am J Clin Nutr* 2014;99:1243s-7s. doi: 10.3945/ajcn.113.073379
7. Cormier H, Thifault E, Garneau V, et al. Association between yogurt consumption, dietary patterns, and cardio-metabolic risk factors. *Eur J Nutr* 2016;55:577-87. doi: 10.1007/s00394-015-0878-1
8. Zhu Y, Wang H, Hollis JH, et al. The associations between yogurt consumption, diet quality, and metabolic profiles in children in the USA. *Eur J Nutr* 2015;54:543-50. doi: 10.1007/s00394-014-0735-7
9. Wang H, Livingston KA, Fox CS, et al. Yogurt consumption is associated with better diet quality and metabolic profile in American men and women. *Nutr Res* 2013;33:18-26. doi: 10.1016/j.nutres.2012.11.009
10. Aune D, Norat T, Romundstad P, et al. Dairy products and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis of cohort studies. *Am J Clin Nutr* 2013;98:1066-83. doi: 10.3945/ajcn.113.059030
11. Gao D, Ning N, Wang C, et al. Dairy products consumption and risk of type 2 diabetes: systematic review and dose-response meta-analysis. *PLoS One* 2013;8:e73965. doi: 10.1371/journal.pone.0073965
12. Chen M, Sun Q, Giovannucci E, et al. Dairy consumption and risk of type 2 diabetes: 3 cohorts of US adults and an updated meta-analysis. *BMC Med* 2014;12:215. doi: 10.1186/s12916-014-0215-1
13. Gijsbers L, Ding EL, Malik VS, et al. Consumption of dairy foods and diabetes incidence: a dose-response meta-analysis of observational studies. *Am J Clin Nutr* 2016;103:1111-24. doi: 10.3945/ajcn.115.123216
14. Tremblay A, Panahi S. Yogurt Consumption as a Signature of a Healthy Diet and Lifestyle. *J Nutr* 2017;147:1476s-80s. doi: 10.3945/jn.116.245522
15. Wu L, Sun D. Consumption of Yogurt and the Incident Risk of Cardiovascular Disease: A Meta-Analysis of Nine Cohort Studies. *Nutrients* 2017;9 doi: 10.3390/nu9030315
16. Guo J, Astrup A, Lovegrove JA, et al. Milk and dairy consumption and risk of cardiovascular diseases and all-cause mortality: dose-response meta-analysis of prospective cohort studies. *EurJ Epidemiol* 2017;32:269-87. doi: 10.1007/s10654-017-0243-1
17. Sayon-Orea C, Martinez-Gonzalez MA, Ruiz-Canela M, et al. Associations between Yogurt Consumption and Weight Gain and Risk of Obesity and Metabolic Syndrome: A Systematic Review. *Adv Nutr* 2017;8:146s-54s. doi: 10.3945/an.115.011536
18. Schwingshackl L, Hoffmann G, Schwedhelm C, et al. Consumption of Dairy Products in Relation to Changes in Anthropometric Variables in Adult Populations: A Systematic Review and Meta-Analysis of Cohort Studies. *PLoS One* 2016;11:e0157461. doi: 10.1371/journal.pone.0157461
19. Santiago S, Sayon-Orea C, Babio N, et al. Yogurt consumption and abdominal obesity reversion in the PREDIMED study. *Nutr Metab Cardiovasc Dis* 2016;26:468-75. doi: 10.1016/j.numecd.2015.11.012

20. Guasch-Ferre M, Becerra-Tomas N, Ruiz-Canela M, et al. Total and subtypes of dietary fat intake and risk of type 2 diabetes mellitus in the Prevencion con Dieta Mediterranea (PREDIMED) study. *Am J Clin Nutr* 2017;105:723-35. doi: 10.3945/ajcn.116.142034
21. Kratz M, Baars T, Guyenet S. The relationship between high-fat dairy consumption and obesity, cardiovascular, and metabolic disease. *Eur J Nutr* 2013;52:1-24. doi: 10.1007/s00394-012-0418-1
22. Weaver CM. How sound is the science behind the dietary recommendations for dairy? *Am J Clin Nutr* 2014;99:1217s-22s. doi: 10.3945/ajcn.113.073007
23. Holmberg S, Thelin A. High dairy fat intake related to less central obesity: a male cohort study with 12 years' follow-up. *Scand J Prim Health Care* 2013;31:89-94. doi: 10.3109/02813432.2012.757070
24. Rautiainen S, Wang L, Lee IM, et al. Dairy consumption in association with weight change and risk of becoming overweight or obese in middle-aged and older women: a prospective cohort study. *Am J Clin Nutr* 2016;103:979-88. doi: 10.3945/ajcn.115.118406
25. Beck AL, Heyman M, Chao C, et al. Full fat milk consumption protects against severe childhood obesity in Latinos. *Prev Med Rep* 2017;8:1-5. doi: 10.1016/j.pmedr.2017.07.005
26. Chowdhury R, Warnakula S, Kunutsor S, et al. Association of dietary, circulating, and supplement fatty acids with coronary risk: a systematic review and meta-analysis. *Ann Intern Med* 2014;160:398-406. doi: 10.7326/m13-1788
27. Williams EB, Hooper B, Spiro A, et al. The contribution of yogurt to nutrient intakes across the life course. *Nutr Bull* 2015;40:9-32. doi: 10.1111/nbu.12130
28. Rizzoli R. Dairy products, yogurts, and bone health. *Am J Clin Nutr* 2014;99:1256s-62s. doi: 10.3945/ajcn.113.073056
29. Salas MM, Nascimento GG, Vargas-Ferreira F, et al. Diet influenced tooth erosion prevalence in children and adolescents: Results of a meta-analysis and meta-regression. *J Dent* 2015;43:865-75. doi: 10.1016/j.jdent.2015.05.012
30. Lythgoe A, Roberts C, Madden AM, et al. Marketing foods to children: a comparison of nutrient content between children's and non-children's products. *Public Health Nutr* 2013;16:2221-30. doi: 10.1017/s1368980013000943
31. Walker RW, Goran MI. Laboratory Determined Sugar Content and Composition of Commercial Infant Formulas, Baby Foods and Common Grocery Items Targeted to Children. *Nutrients* 2015;7:5850-67. doi: 10.3390/nu7075254
32. Azais-Braesco V, Sluik D, Maillot M, et al. A review of total & added sugar intakes and dietary sources in Europe. *Nutr J* 2017;16:6. doi: 10.1186/s12937-016-0225-2
33. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. *J Dent Res* 2014;93:8-18. doi: 10.1177/0022034513508954
34. Moore JB, Fielding BA. Sugar and metabolic health: is there still a debate? *Curr Opin Clin Nutr Metab Care* 2016;19:303-09. doi: 10.1097/MCO.0000000000000289
35. National Statistics. Statistics on Obesity, Physical Activity and Diet, England 2017. 2017
36. Scientific Advisory Committee on Nutrition. Carbohydrates and Health. London: The Stationery Office, 2015.
37. Public Health England. Sugar reduction: Achieving the 20%, 2017.
38. Kantar Worldpanel. Grocery market Share for Great Britain 2017 [Available from: https://www.kantarworldpanel.com/en/grocery-market-share/great-britain accessed November 24th, 2017
39. Roberts C, Steer T, Maplethorpe N, et al. National Diet and Nutrition Survey: Results from Years 7 and 8 (combined) of the Rolling Programme (2014/2015 to 2015/2016). *https://wwwgovuk/government/statistics/ndns-results-from-years-7-and-8-combined* 2018
40. Department of Health UK. Guide to creating a front of pack (FoP) nutrition label for pre-packed products sold through retail outlets. *https://wwwgovuk/government/publications/front-of-pack-nutrition-labelling-guidance* 2016
41. Nguyen PK, Lin S, Heidenreich P. A systematic comparison of sugar content in low-fat vs regular versions of food. *Nutr Diabetes* 2016;6:e193. doi: 10.1038/nutd.2015.43

42. Public Health England. National Dental Epidemiology Programme for England: Oral health survey of five-year-old children 2012 A report on the prevalence and severity of dental decay. 2012
43. Royal College of Surgeons: Faculty of Dental Surgery. The state of children's oral health in England. 2015
44. Health and Social Care Information Centre. Statistics on Obesity, Physical Activity and Diet: England 2017 2017 [Available from: https://www.gov.uk/government/statistics/statistics-on-obesity-physical-activity-and-diet-england-2017.
45. Lee W-cJ, Shimizu M, Kniffin KM, et al. You taste what you see: Do organic labels bias taste perceptions? *Food Qual Pref* 2013;29:33-39. doi: https://doi.org/10.1016/j.foodqual.2013.01.010
46. Food and Drug Administration. Food Labeling: Revision of the Nutrition and Supplement Facts Labels. *Federal Register*;81:Docket No. FDA–2012–N–1210.
47. Mela DJ, Woolner EM. Perspective: Total, Added, or Free? What Kind of Sugars Should We Be Talking About? *Adv Nutr* 2018;9:63-69. doi: 10.1093/advances/nmx020
48. Te Morenga LA, Howatson AJ, Jones RM, et al. Dietary sugars and cardiometabolic risk: systematic review and meta-analyses of randomized controlled trials of the effects on blood pressure and lipids. *Am J Clin Nutr* 2014;100:65-79. doi: 10.3945/ajcn.113.081521
49. Chinachoti P. Carbohydrates: functionality in foods. *Am J Clin Nutr* 1995;61:922s-29s.
50. Bayarri S, Carbonell I, Barrios EX, et al. Impact of sensory differences on consumer acceptability of yoghurt and yoghurt-like products. *Int Dairy J* 2011;21:111-18. doi: https://doi.org/10.1016/j.idairyj.2010.09.002
51. Johansen SB, Næs T, Øyaas J, et al. Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Qual Pref* 2010;21:13-21. doi: https://doi.org/10.1016/j.foodqual.2009.07.003
52. Chollet M, Gille D, Schmid A, et al. Acceptance of sugar reduction in flavored yogurt. *J Dairy Sci* 2013;96:5501-11. doi: 10.3168/jds.2013-6610
53. Saint-Eve A, Leclercq H, Berthelo S, et al. How much sugar do consumers add to plain yogurts? Insights from a study examining French consumer behavior and self-reported habits. *Appetite* 2016;99:277-84. doi: 10.1016/j.appet.2016.01.032
54. Wolever TM. Yogurt Is a Low-Glycemic Index Food. *J Nutr* 2017;147:1462s-67s. doi: 10.3945/jn.116.240770
55. Gupta P, Gupta N, Pawar AP, et al. Role of sugar and sugar substitutes in dental caries: a review. *ISRN dentistry* 2013;2013:519421. doi: 10.1155/2013/519421
56. Aimutis WR. Lactose cariogenicity with an emphasis on childhood dental caries. *Int Dairy J* 2012;22:152-58. doi: https://doi.org/10.1016/j.idairyj.2011.10.007
57. Drewnowski A, Mennella JA, Johnson SL, et al. Sweetness and food preference. *J Nutr* 2012;142:1142s-8s. doi: 10.3945/jn.111.149575
58. Dobbs R, Sawers C, Thompson F, et al. Overcoming obesity: An initial economic analysis: McKinsey Global Institution, 2014.
59. Scharf RJ, Demmer RT, DeBoer MD. Longitudinal evaluation of milk type consumed and weight status in preschoolers. *Arch Dis Child* 2013;98:335-40. doi: 10.1136/archdischild-2012-302941
60. Bigornia SJ, LaValley MP, Moore LL, et al. Dairy intakes at age 10 years do not adversely affect risk of excess adiposity at 13 years. *J Nutr* 2014;144:1081-90. doi: 10.3945/jn.113.183640
61. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition ed, 2015.
62. Public Health England. McCance and Widdowson's The Composition of Foods Integrated Dataset, 2015.

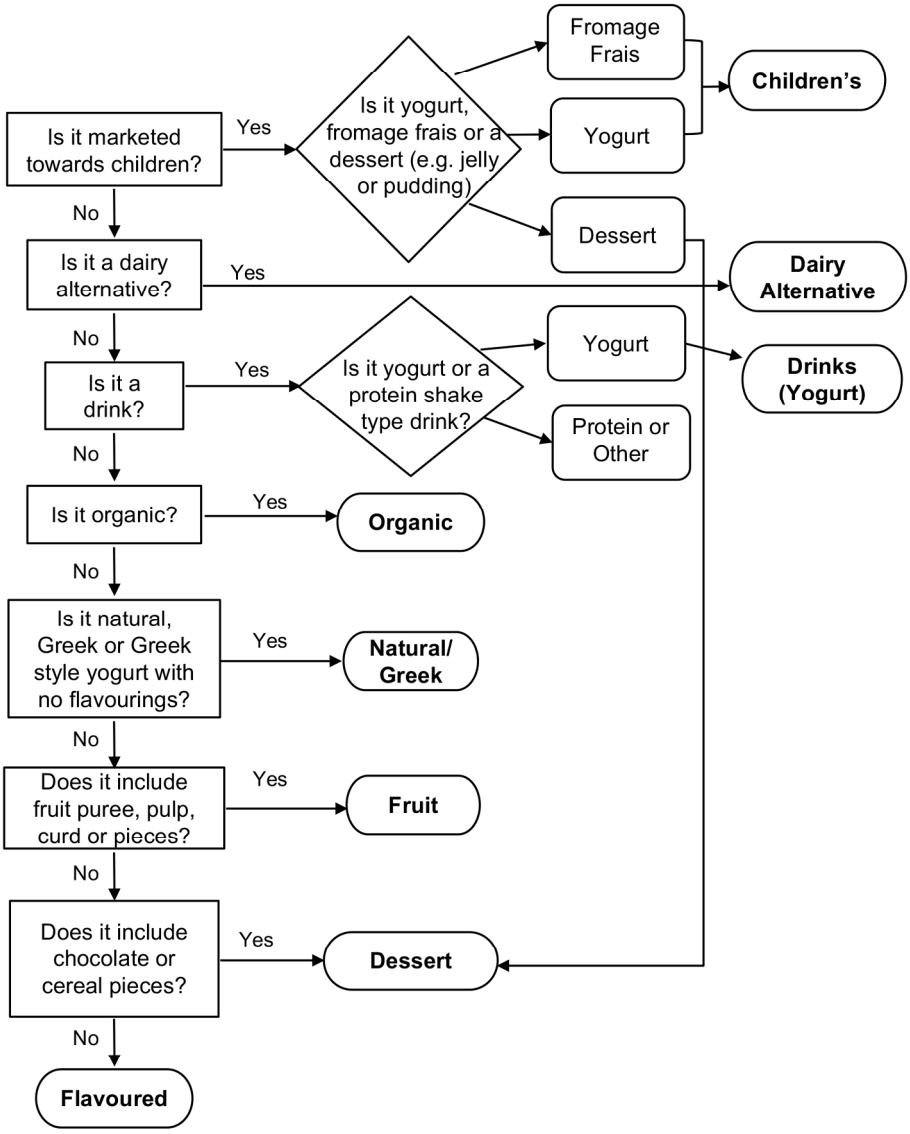

Figure 1. Process flow diagram of category decision. Data were collected using yogurt as a search term within the UK's top five online supermarkets between 07/10/16- 16/11/16. Products were classified into different categories as shown.

175x214mm (300 x 300 DPI)

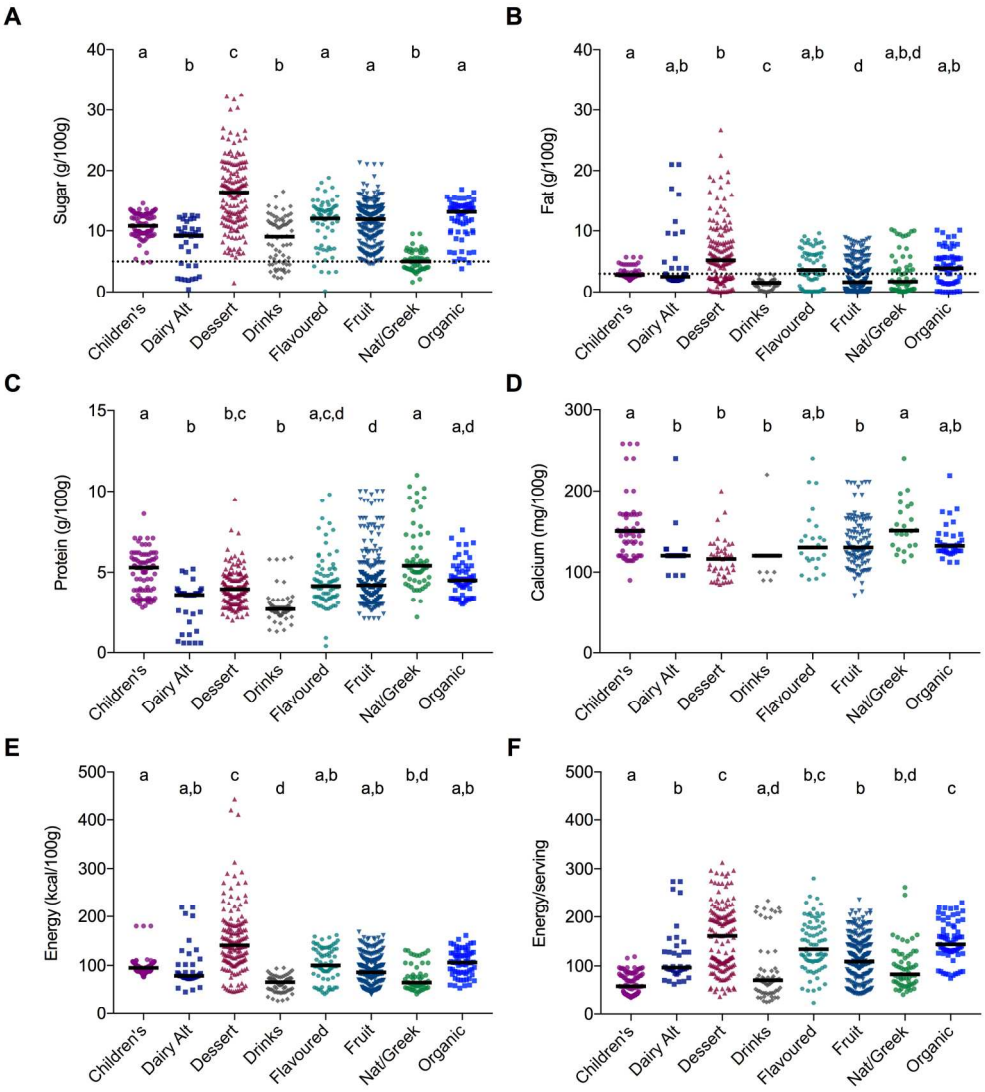

Figure 2. Nutrient and energy contents of UK yogurt products across categories. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Kruskal-Wallis and Dunn's multiple comparison tests; categories with unlike letters were significantly different. Median is indicated by black line. Dashed lines indicate thresholds defined by EU regulations2 for nutrition claims for low-sugar A and low fat B.

176x196mm (300 x 300 DPI)

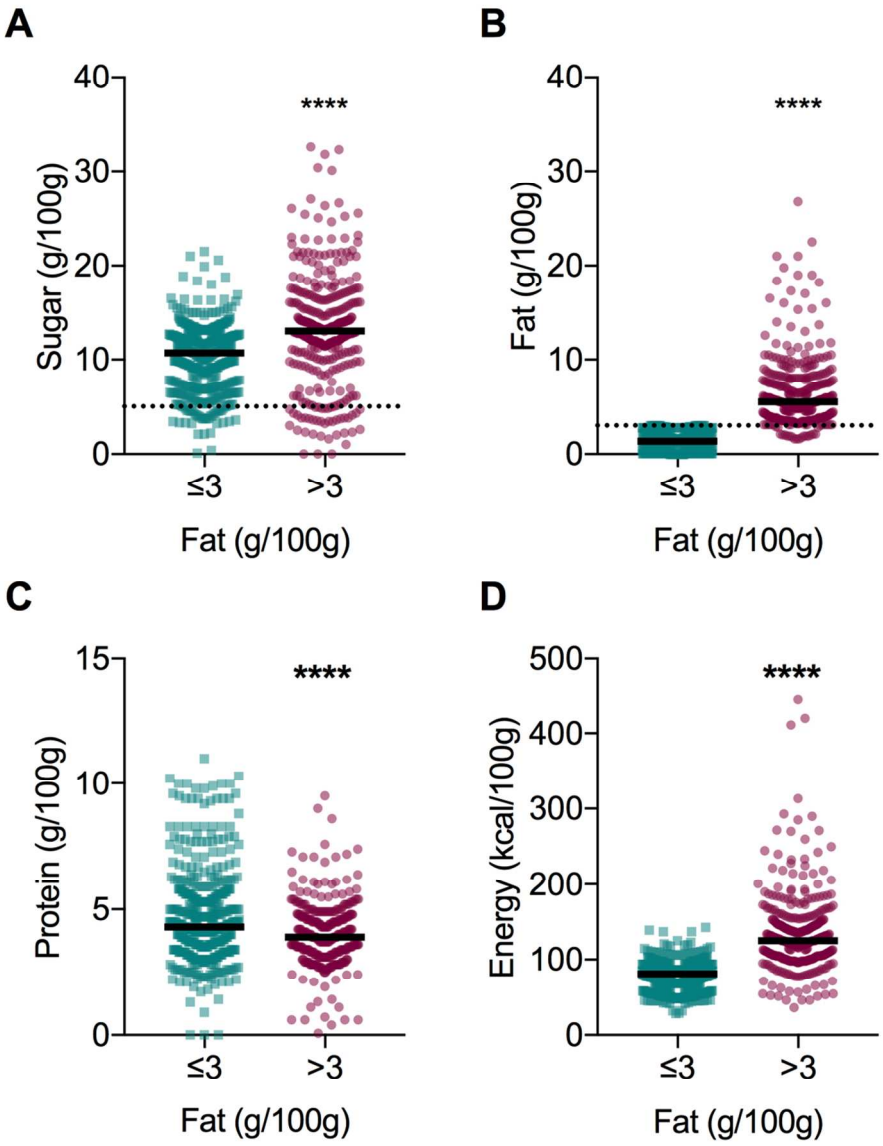

Figure 3. Macronutrients compared across low- (≤3g/100g; n=530) and higher- (>3g/100g; n=383) fat products. A Sugar. B Fat. C Protein. D Energy. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. ****P<0.0001.

108x129mm (300 x 300 DPI)

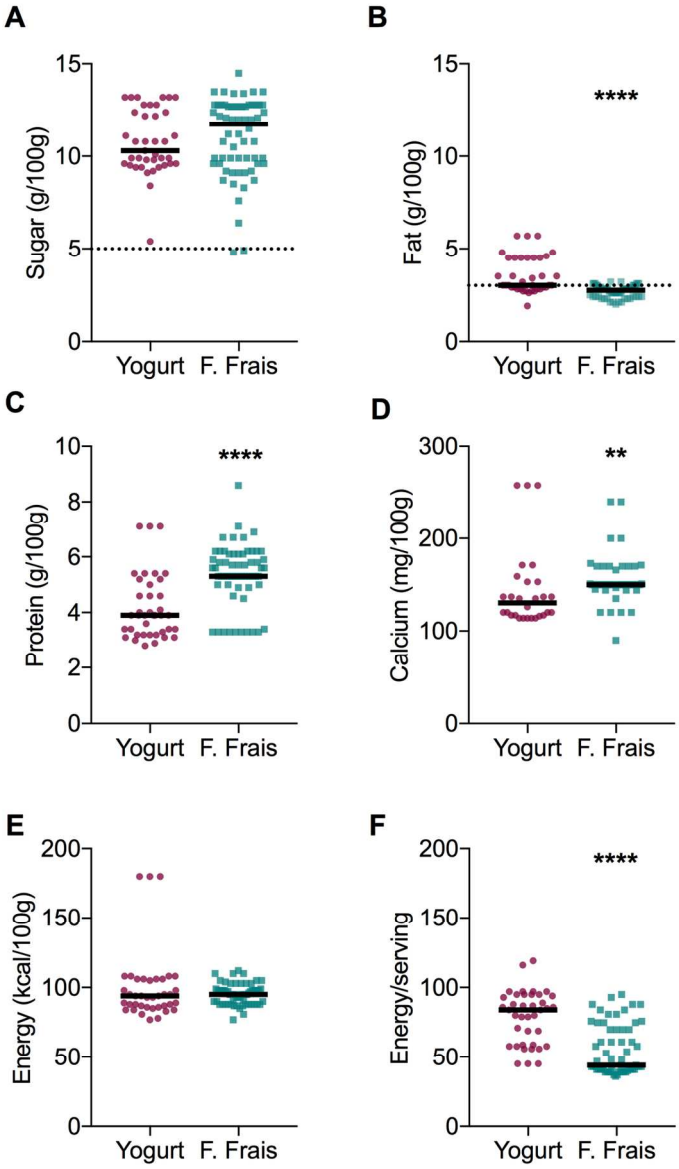

Figure 4. Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. A Sugar. B Fat. C Protein. D Calcium. E Energy. F Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.

114x176mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **Done p1, p2**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Done p2**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Done p4 and p5**
Objectives	3	State specific objectives, including any prespecified hypotheses **Done p6**
Methods		
Study design	4	Present key elements of study design early in the paper **Done p7**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Done p7 (recruitment N/A)**
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case **Not applicable**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Figure 4.** Nutrients in children's yogurt (n=39) and fromage frais (F. Frais; n=62) products. **A** Sugar. **B** Fat. **C** Protein. **D** Calcium. **E** Energy. **F** Energy/serving. Data were tested for normality and analysed using the Mann-Whitney test. Median is indicated by black line. **P<0.01, ***P<0.001 ****P<0.0001.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Done p7**
Bias	9	Describe any efforts to address potential sources of bias **Done p12_L311-319**
Study size	10	Explain how the study size was arrived at **Done p7 and p12_L311-315**

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Done p7**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses **Done p7**

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram **Not applicable**
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) **Not applicable**
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures **Not applicable**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Not applicable**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses **Done p7**
Discussion		
Key results	18	Summarise key results with reference to study objectives **Done p10**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Done p12**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Done p12-13 L313-314**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Done p12_L321-335**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Done p14**

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.